

# Sensitivity of tropical tropospheric composition to lightning- NO production and ENSO

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## Outline

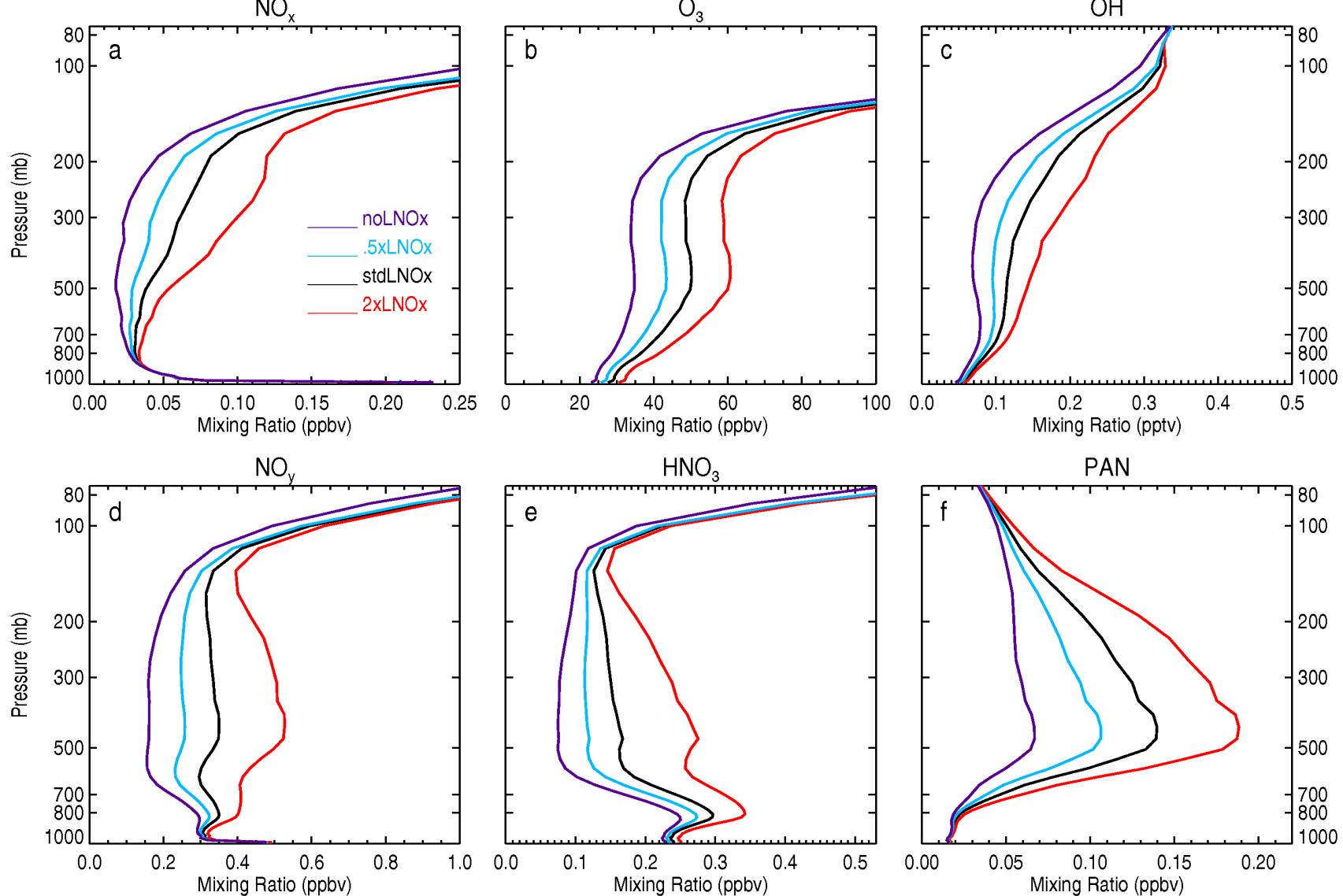
- Model NO<sub>2</sub> and O<sub>3</sub> are compared to OMI and TES for lightning-NO sources of 0, 2.5, 5, and 10 N / yr during the Sep-Nov 2007 time period (C. Liaskos, in prep, 2014)
- Radiative flux due to ozone attributable to lightning is shown
- El Nino (2006) – La Nina (2007) differences in lower-, middle-, and upper-tropospheric CO are compared for the Oct15-Nov14 time period using MOPITT, AIRS, TES, and MLS CO products

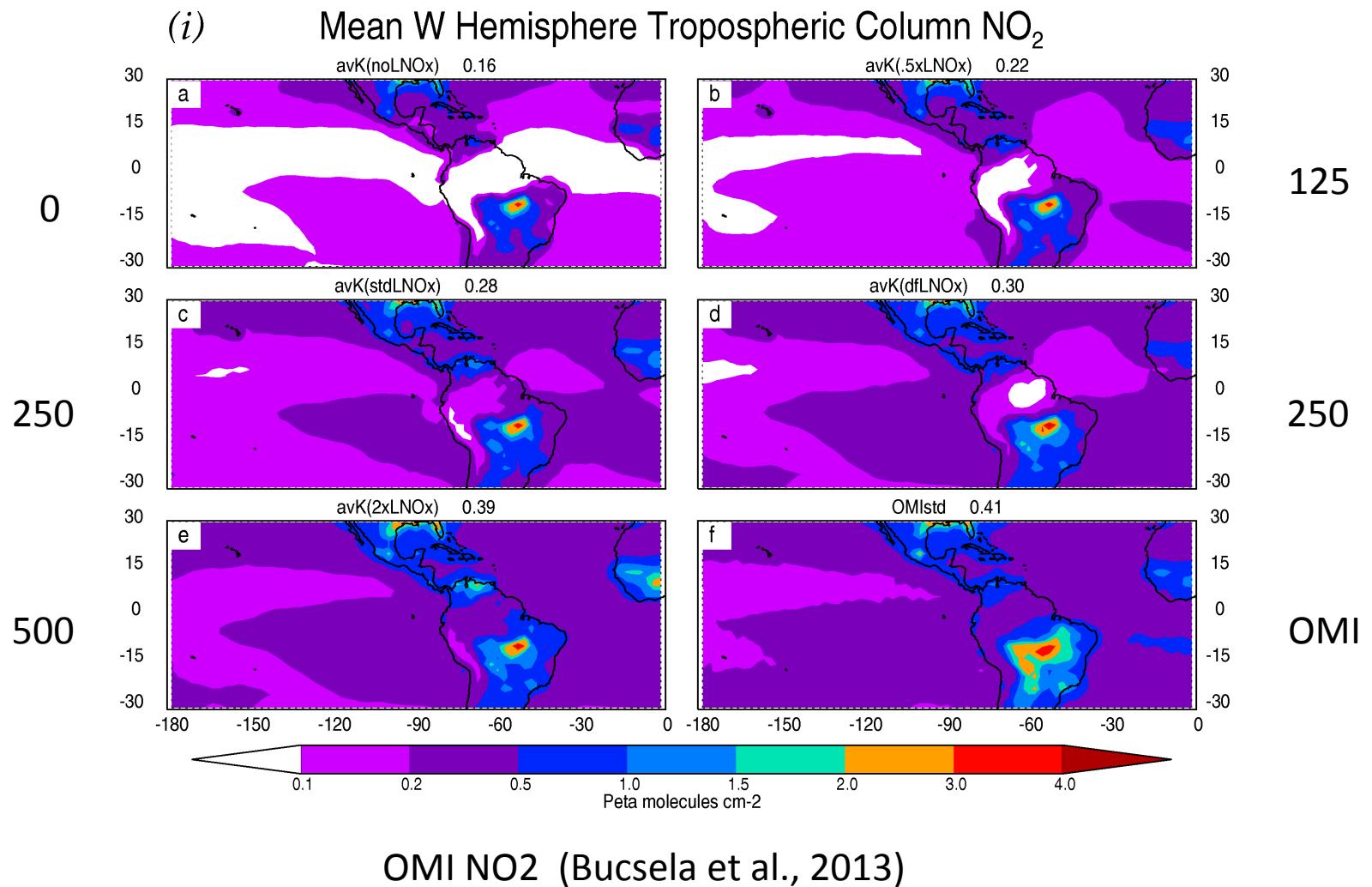
# NASA GEOS-5 CCM

- NASA GEOS-5 CCM was run in replay mode (ozone was not replayed) utilizing MERRA reanalysis data to constrain model dynamics
- Base Run Time Period: June 2006 to March 2008 (5.0 Tg N / yr LNOx)
- Sensitivity Runs with lightning-NO sources of 0, 2.5, 5.0, and 10.0 Tg N / yr were run for Jun-Dec 2007 (Sep-Nov analyzed).
- A sensitivity run with a fixed (monthly climatology) 5.0 Tg N source of LNOx was also run for Jun-Dec 2007.
- $2.0^\circ \times 2.5^\circ$  resolution with 72 vertical layers and 0.01 hPa model top
- LNOx source is assumed to be proportional to the sum of normalized integrated cold-core convective mass flux and normalized surface temperature-cubed perturbation from 273 K.
  - separate continental and marine fits
  - Each term is normalized by its five-year mean before use.

# Zonally-Averaged Atmospheric Profiles 22°N to 22°S

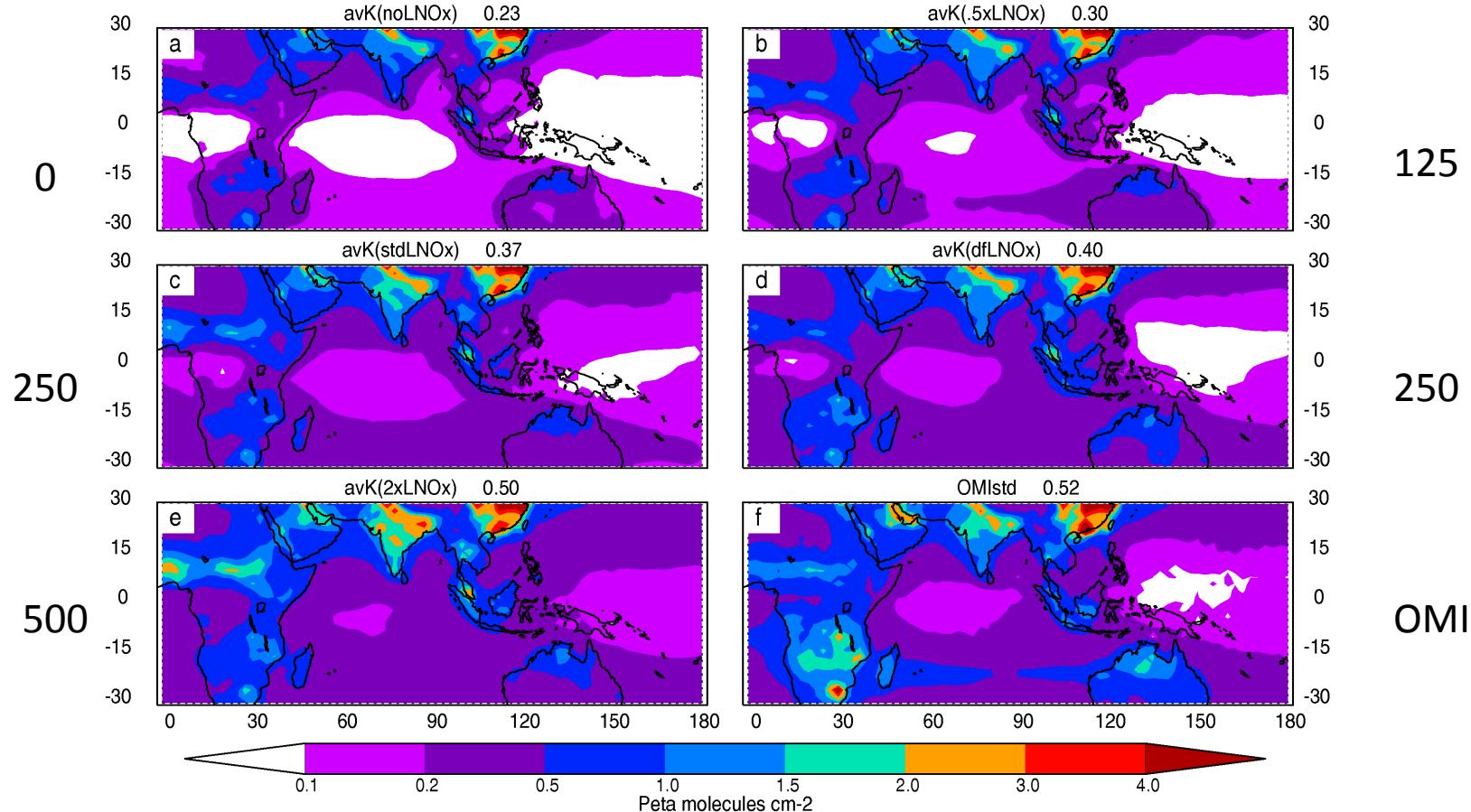
SON 2007



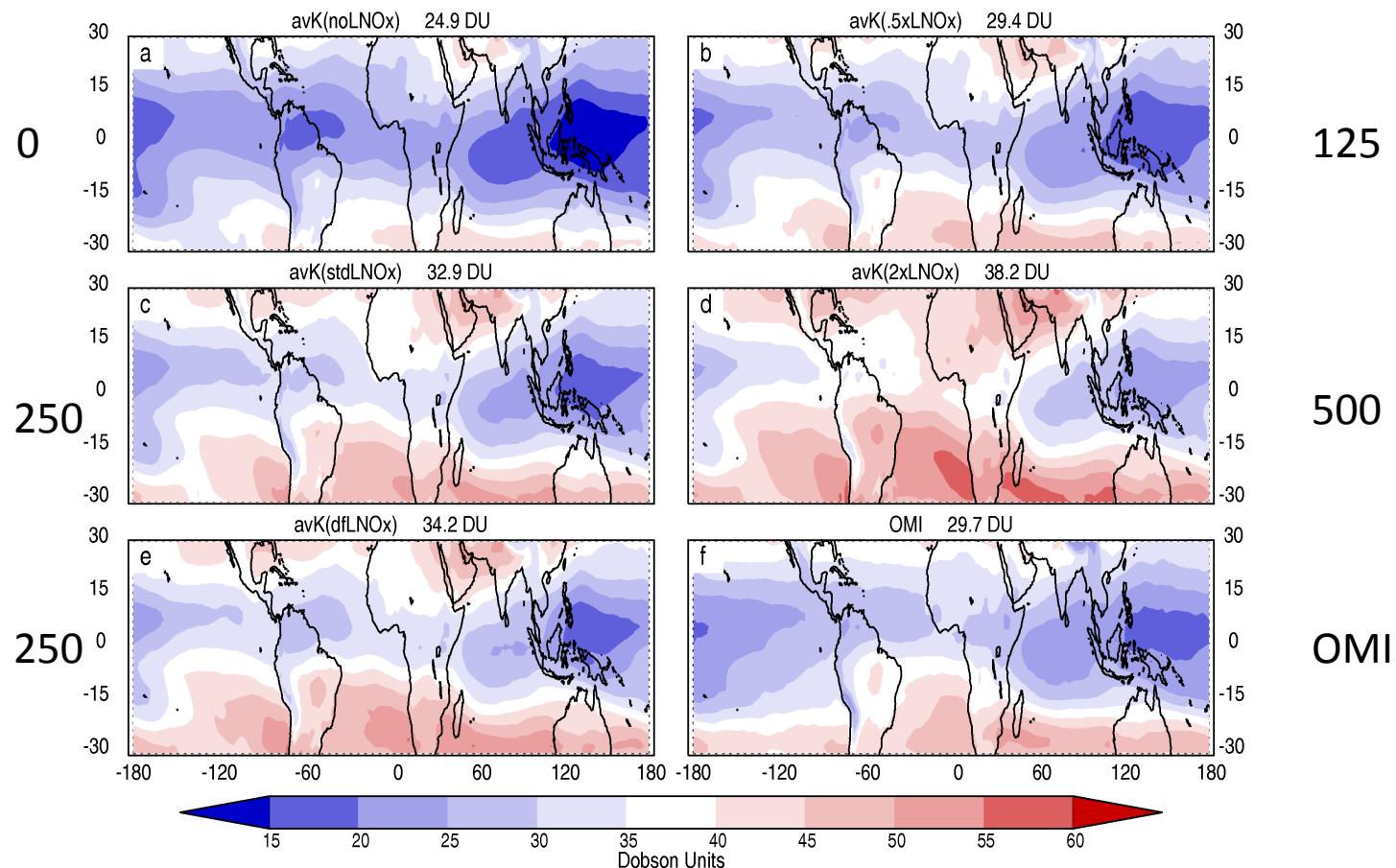


(ii)

### Mean E Hemisphere Tropospheric Column NO<sub>2</sub>



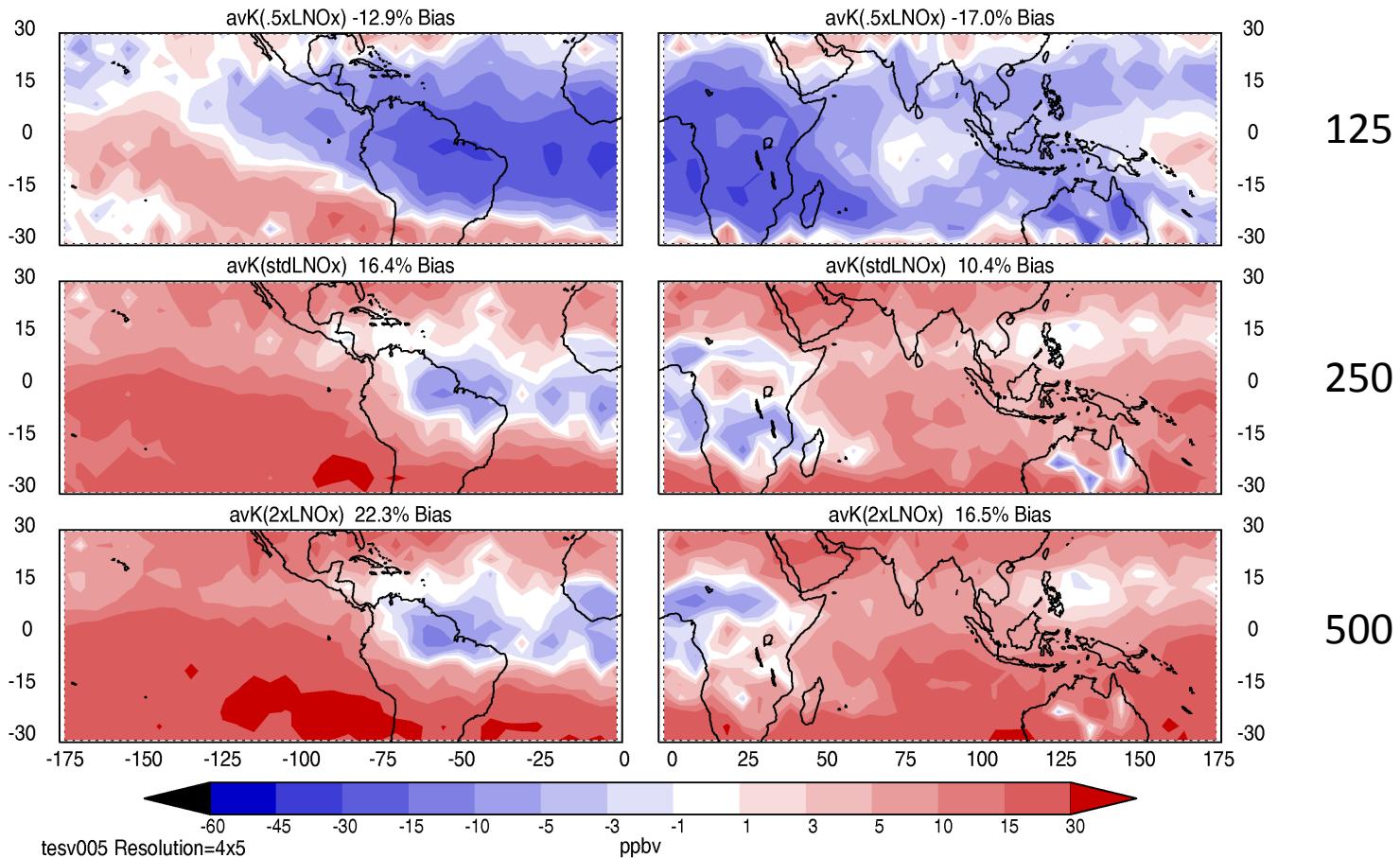
## NASA-GSFC CCM and OMI TCO



OMI TCO (Liu et al., 2010)

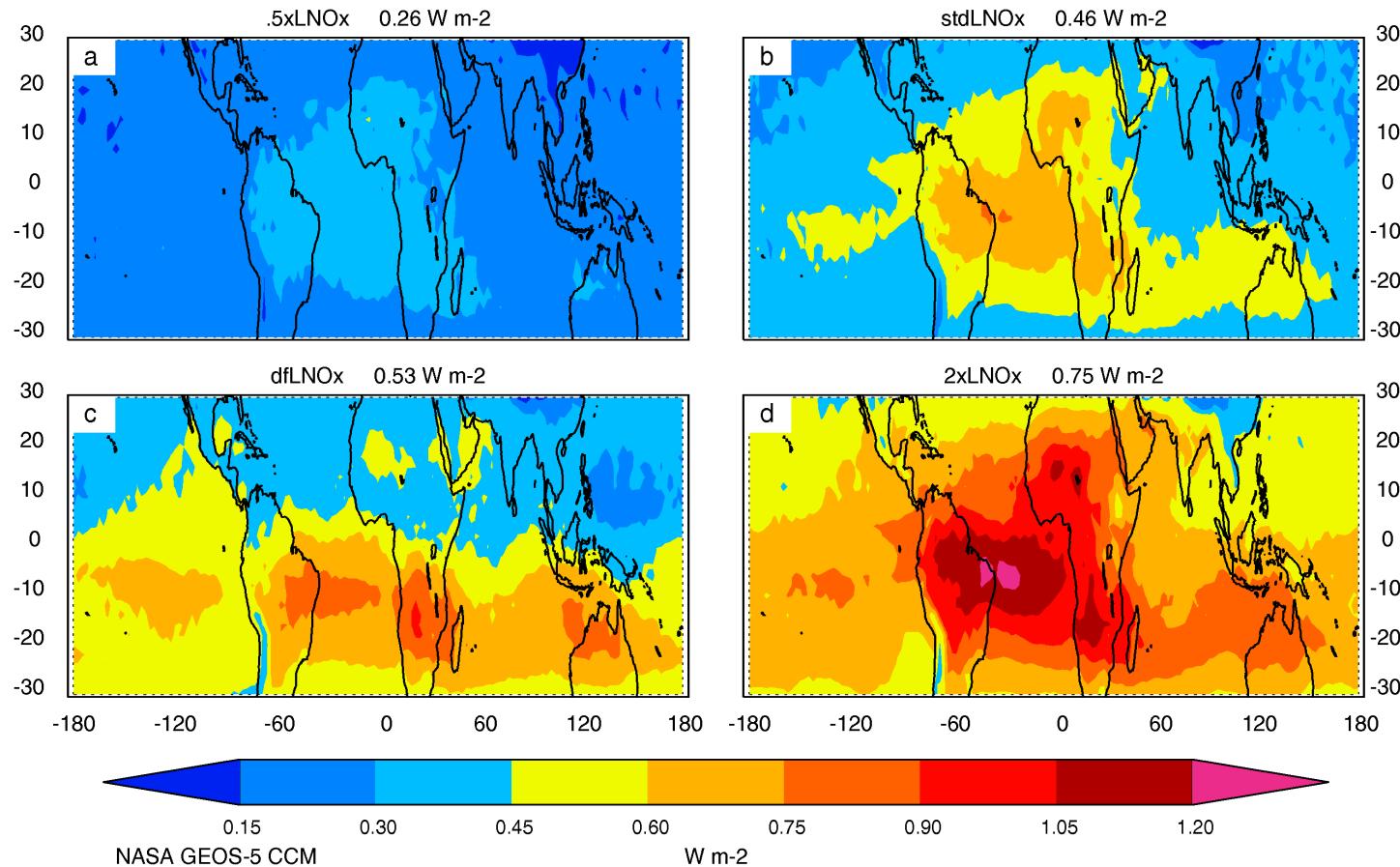
(i)

### Mean O<sub>3</sub> Bias with Respect to TES at 261 hPa



TES ozone (Herman et al., 2012)

## SON Mean Radiative Flux at 163.66 hPa



Change in 164 hPa radiative flux attributable to ozone with a LNOx source

## Conclusions

- Mean CCM 300 hPa tropical ozone equals 30, 40, 50 and 60 ppbv for LNOx sources of 0, 125, 250, and 500 moles per flash. Mean OH for the same LNOx sources equals 0.07, 0.10, 0.18, and 0.18 ppbv.
- Tropical tropospheric NO<sub>2</sub> columns from the CCM are biased low wrt to OMI, while tropical tropospheric O<sub>3</sub> columns tend to be biased high.
- Tropical UT O<sub>3</sub> agrees best with a 125 mole per flash LNOx source in the tropics.
- Halving (doubling) LNOx production from 250 moles per flash changes the mean tropical downward radiative flux at 163 hPa due only to ozone attributable to lightning by -43 (+63%)

# How consistent are satellite-retrieved estimates of CO?

- Time periods considered:
  - Oct15-Nov 14, 2006 (El Nino)
  - Oct15-Nov 15, 2007 (La Nina)

Altitudes considered:

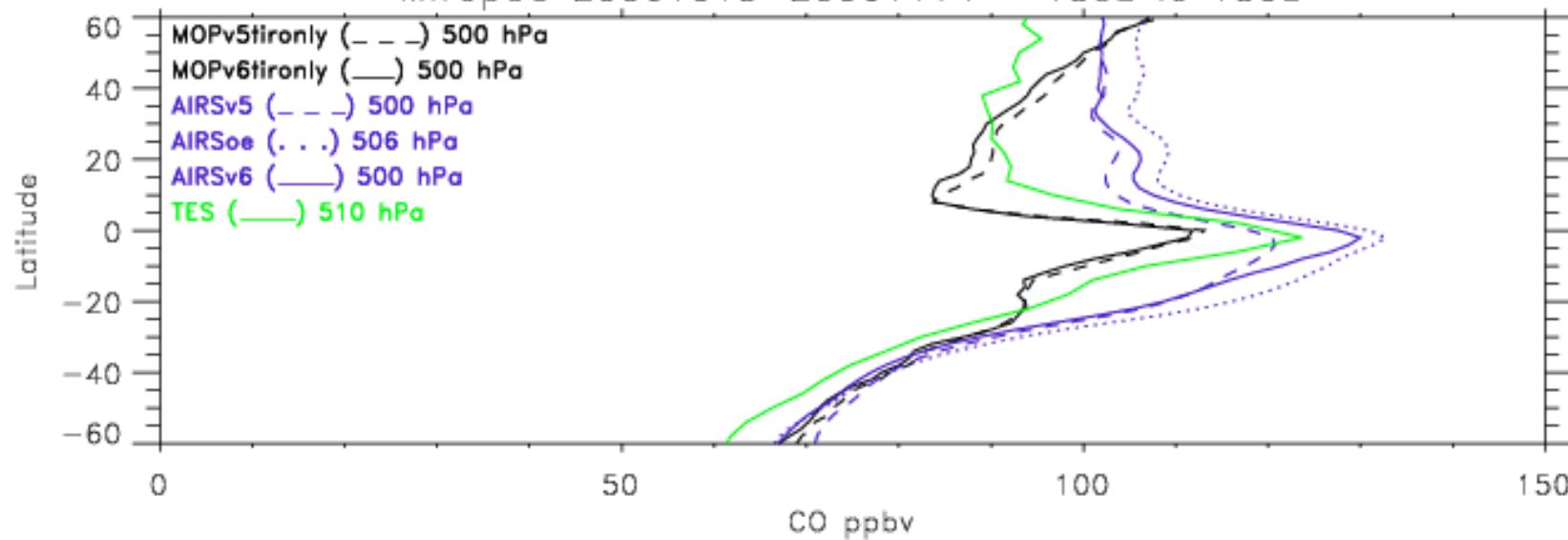
Lower (~850 hPa), middle (~500 hPa), and upper (~250 hPa) troposphere

- Compare zonal average profiles during 2006 and 2007
- Compare surface plots during 2006
- Compare El Nino – La Nina differences
- How correlated are 2006-2007 changes between the various products?

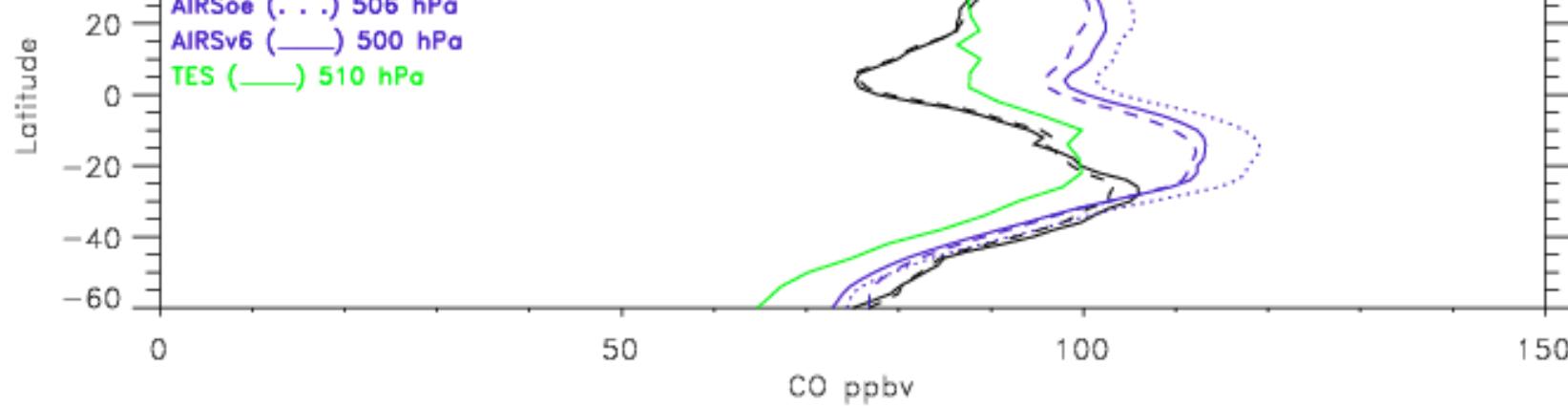
# CO products considered

- MOPITT CO (H. Worden et al., 2010; Deeter et al., 2011, 2013)
- V5 (V6) product uses NCEP (higher resolution MERRA) met fds
- V5 (V6) product a priori based on MOZART 1997-2004 (CAM-CHEM 2000-2009)
- TIRNIR products takes advantage of TIR mid-tropospheric sensitivity and NIR total column sensitivity
- AIRS CO (Warner et al., 2010; McMillan et al., 2011)
- V6 product uses updated a priori (monthly climatology)
- AIRSoe product is based on V5 but uses optimal estimation
- TES v005 CO (Ho et al., 2009; Herman and Osterman, 2012)
- MLS v3.3 CO (Livesey et al., 2011)

MtropCO 20061015–20061114 -180E to 180E

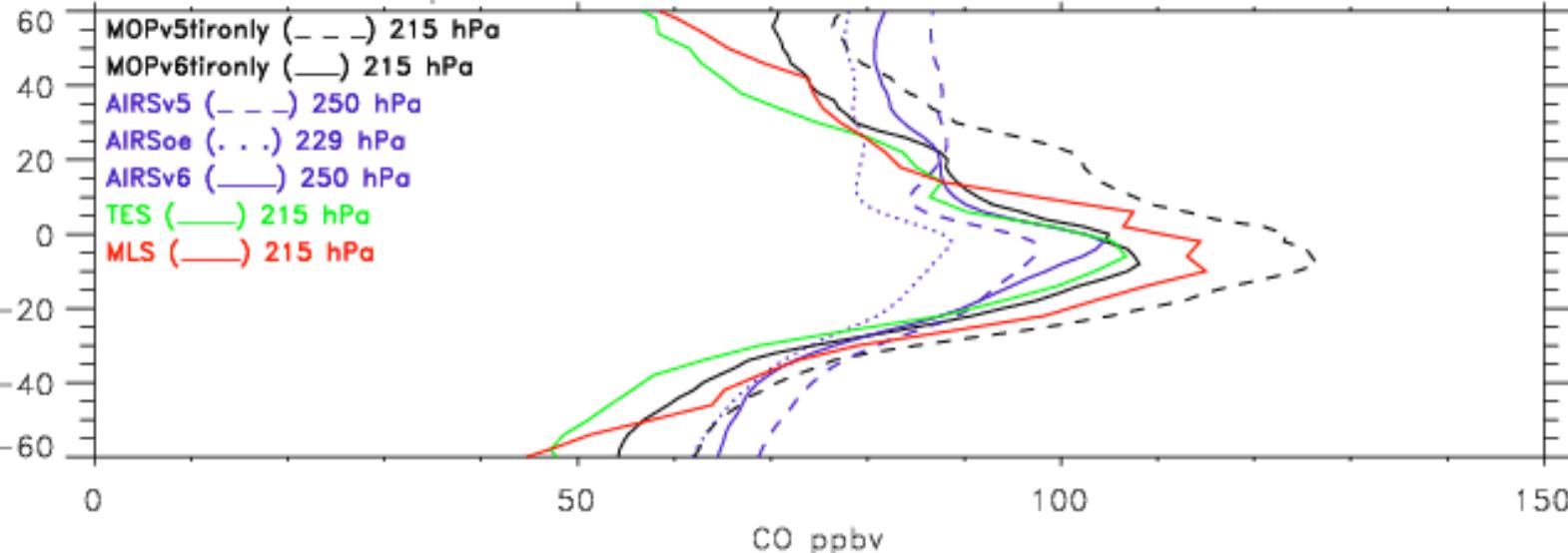


MtropCO 20071015–20071114 -180E to 180E



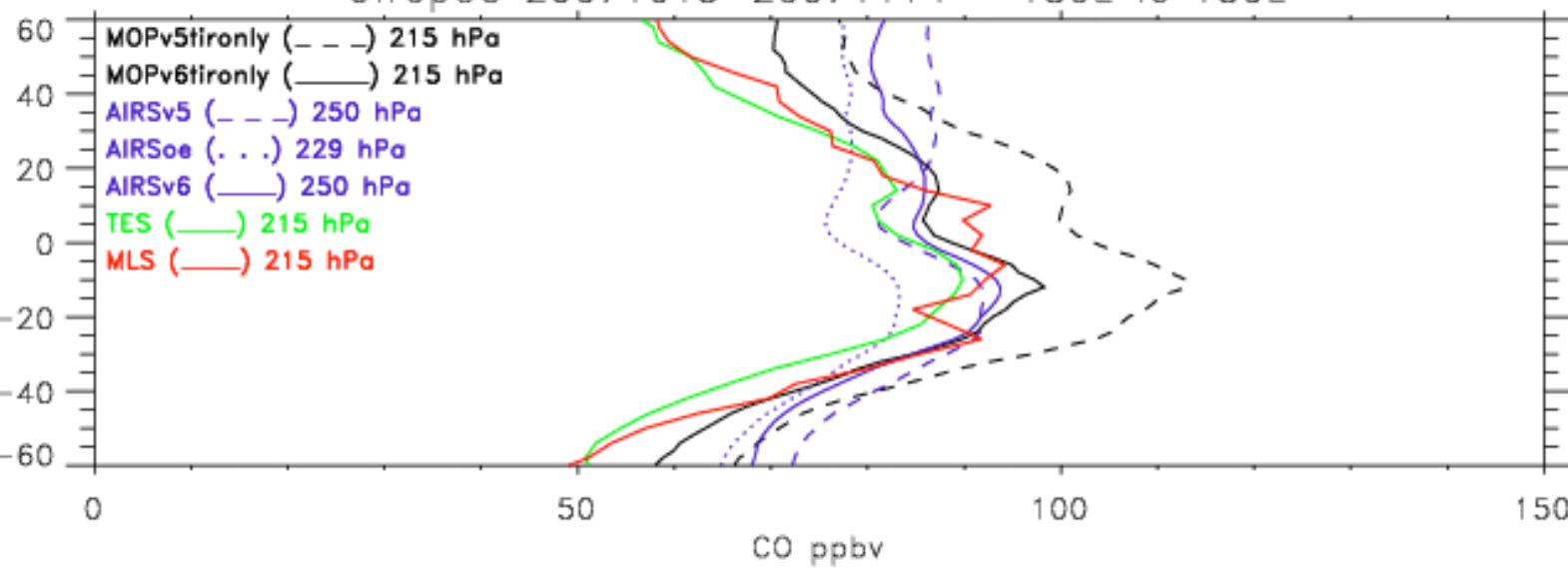
UtropCO 20061015–20061114 -180E to 180E

Latitude



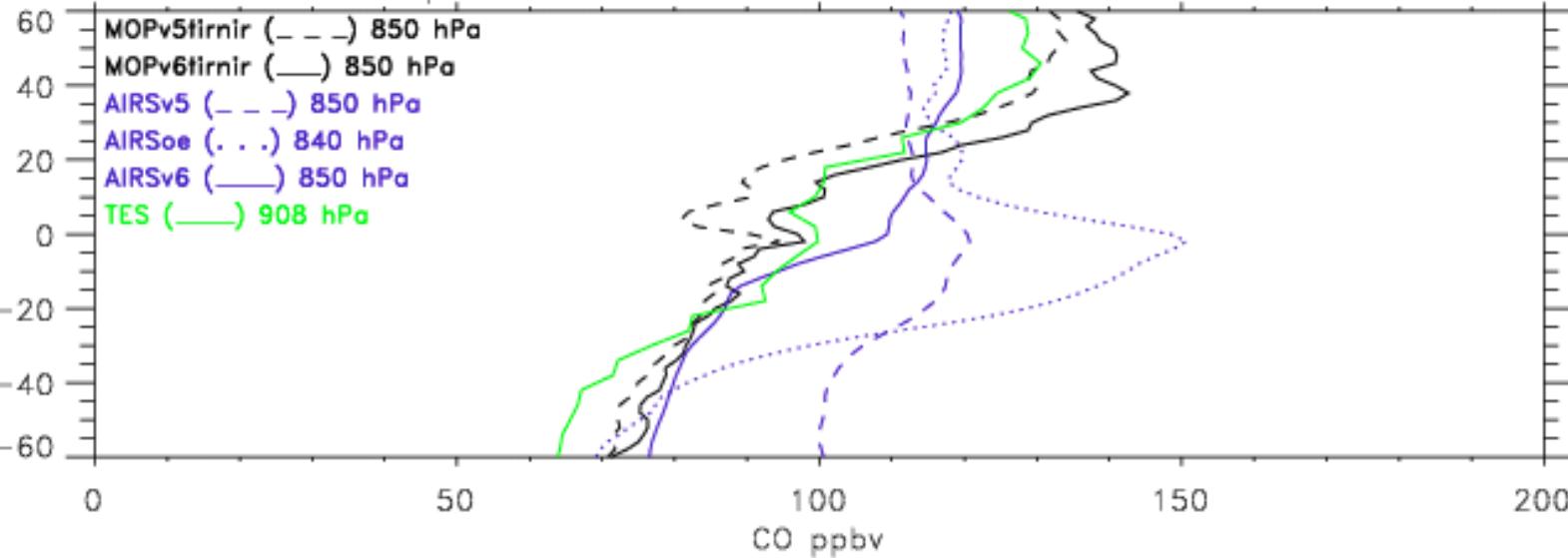
UtropCO 20071015–20071114 -180E to 180E

Latitude



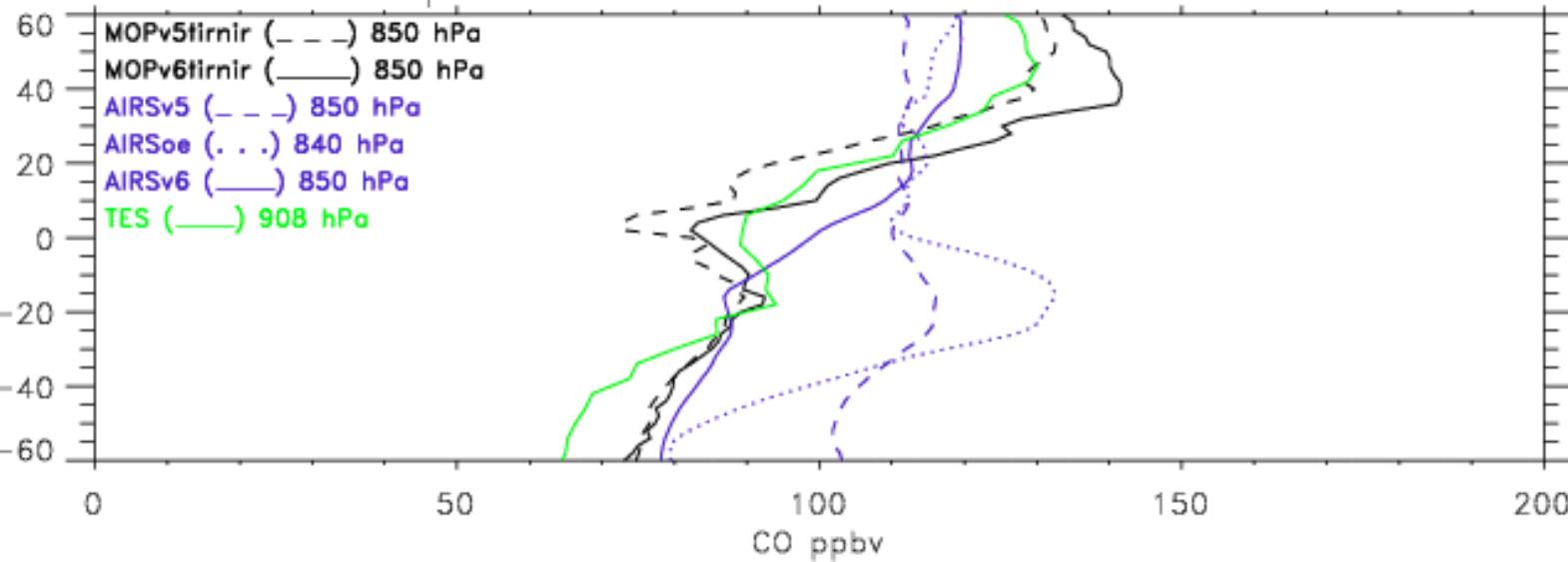
LtropCO 20061015–20061114 -180E to 180E

Latitude

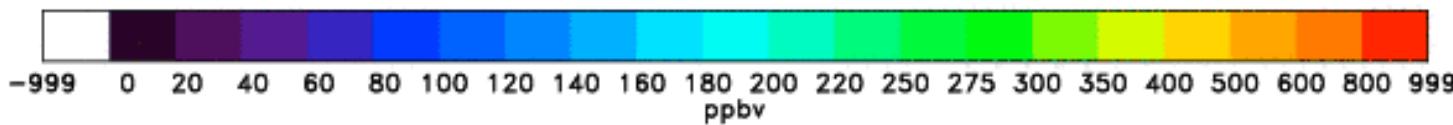
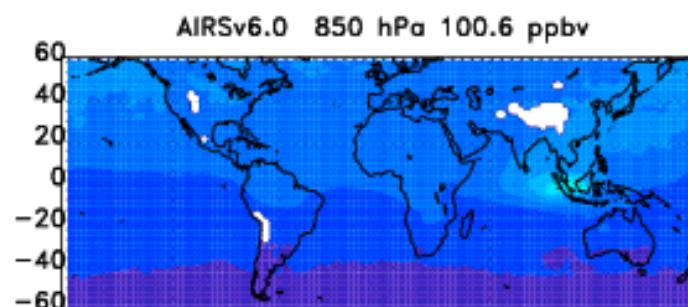
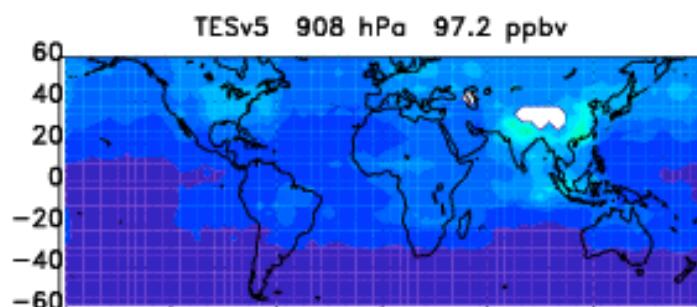
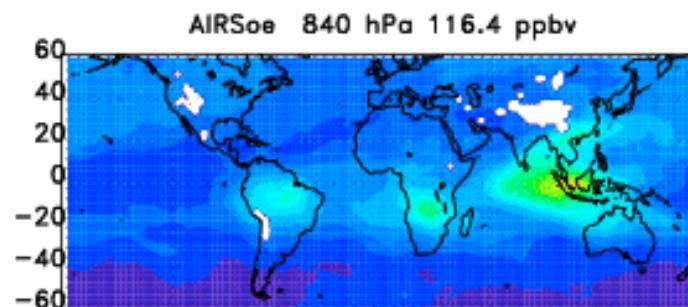
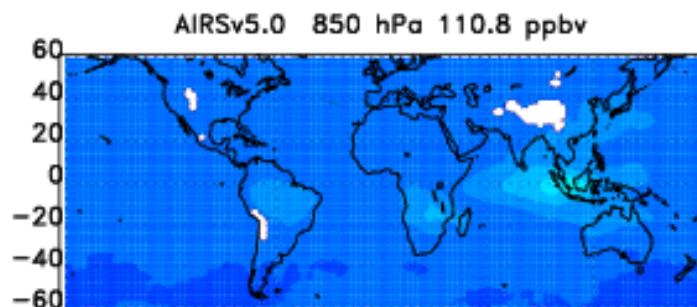
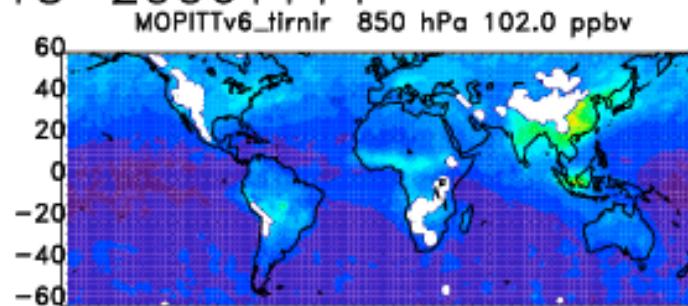
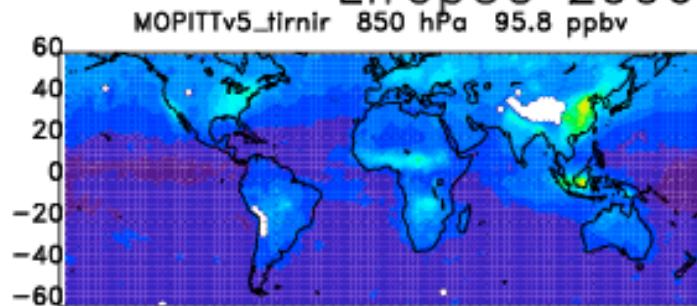


LtropCO 20071015–20071114 -180E to 180E

Latitude



# LtropCO 20061015–20061114

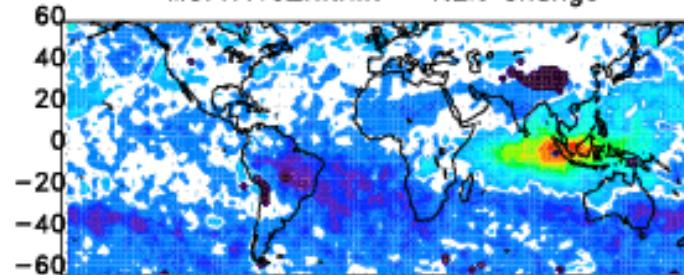
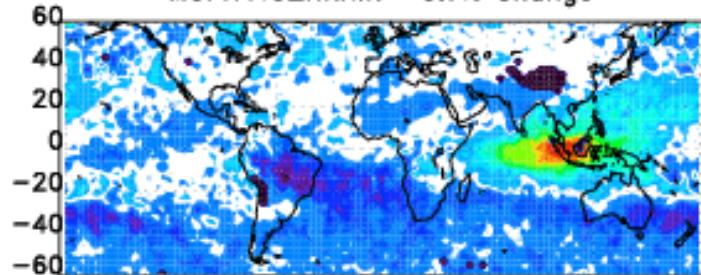


MOPITT & AIRS (2x2.5 degrees); TES & MLS (4x5 degrees)

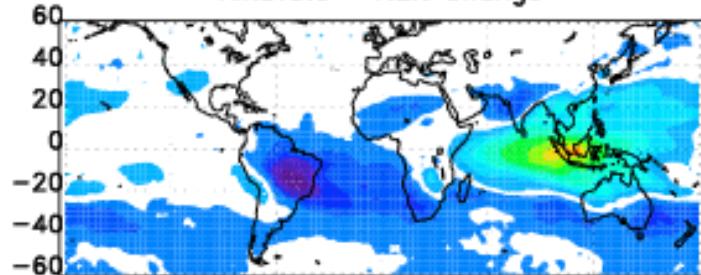
# MtropCO:Nino(06)–Nina(07) Oct15–Nov14

MOPITTv5\_TIRNIR 0.7% Change

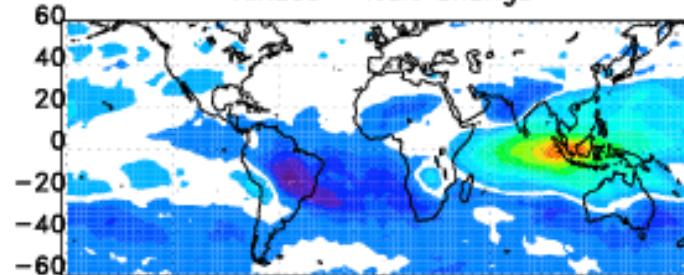
MOPITTv6\_TIRNIR -1.2% Change



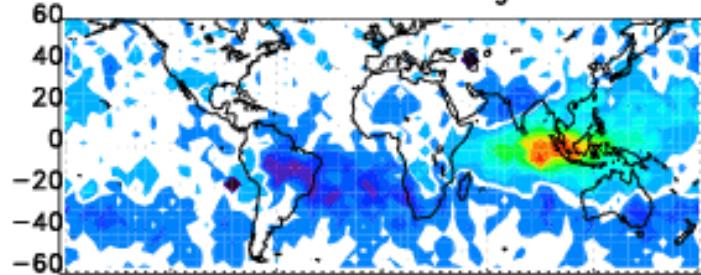
AIRSv5.0 1.2% Change



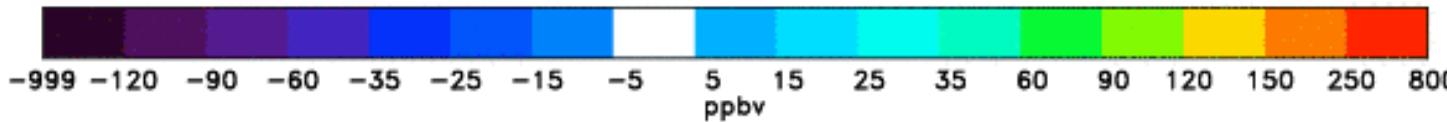
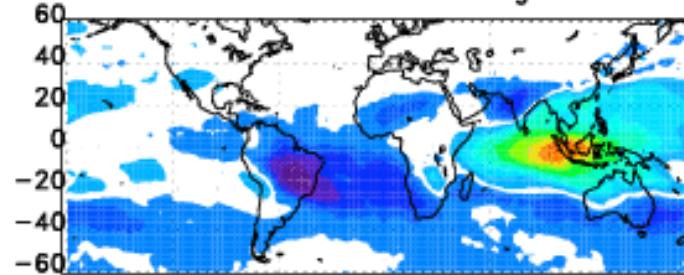
AIRSoe 1.6% Change



TESv5 3.7% Change



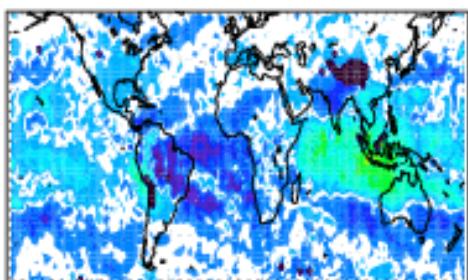
AIRSv6.0 1.7% Change



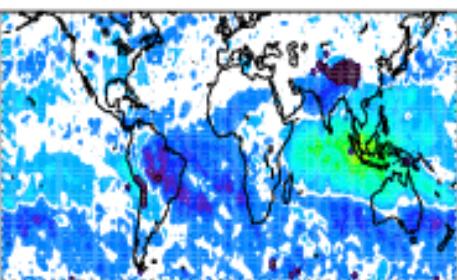
2x2.5MOPITT 500 hPa 2x2.5AIRSv5 500 hPa 2x2.5AIRSoe 506 hPa 4x5TESv5 510 hPa 2x2.5AIRSv6 500 hPa

# UrtropCO:Nino(06)–Nina(07) Oct15–Nov14

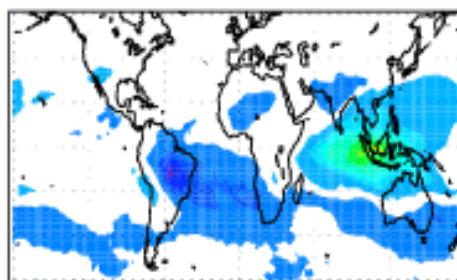
MOPITTv5\_TIRNIR 3.1% Change



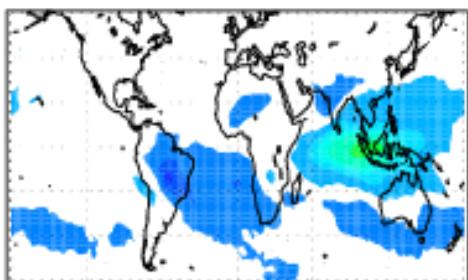
MOPITTv6\_TIRNIR 2.2% Change



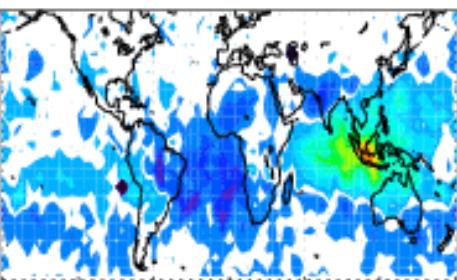
AIRSv5.0 0.6% Change



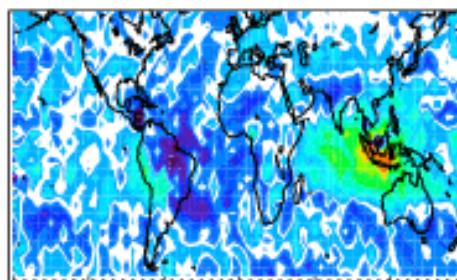
AIRSoe 0.8% Change



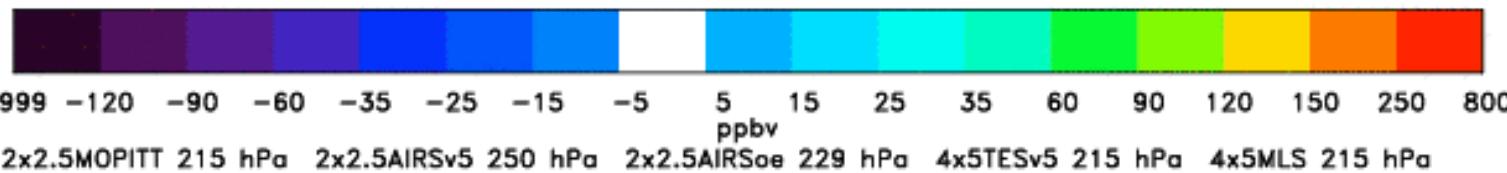
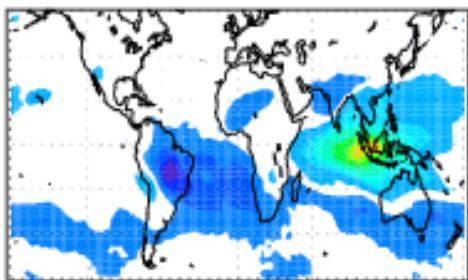
TESv5 4.1% Change



MLSv3 7.4% Change



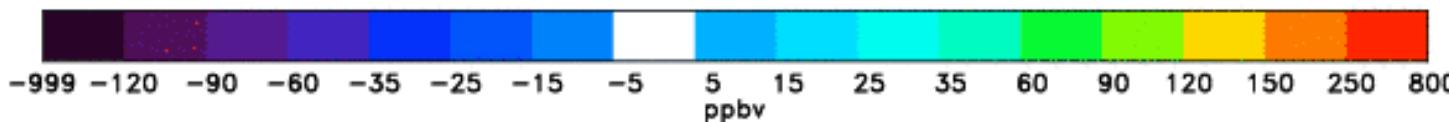
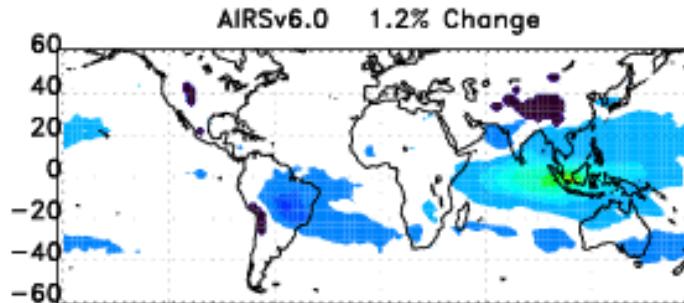
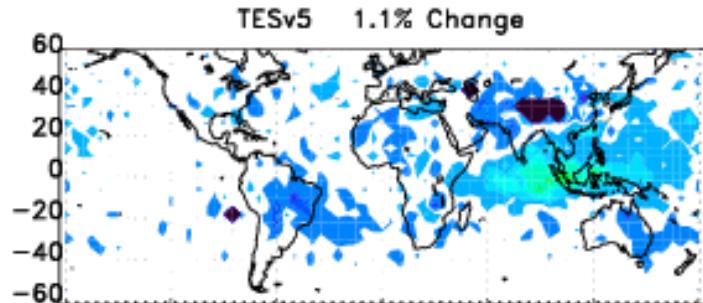
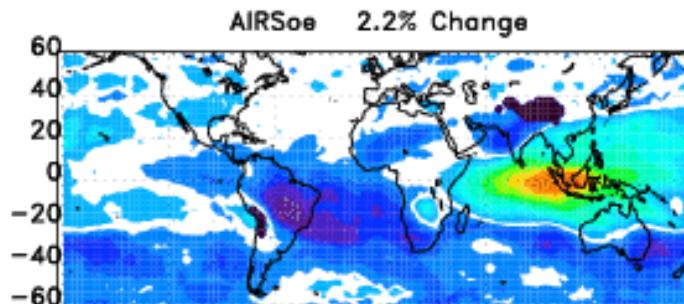
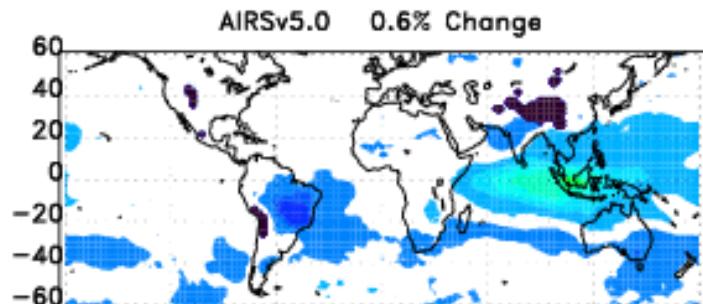
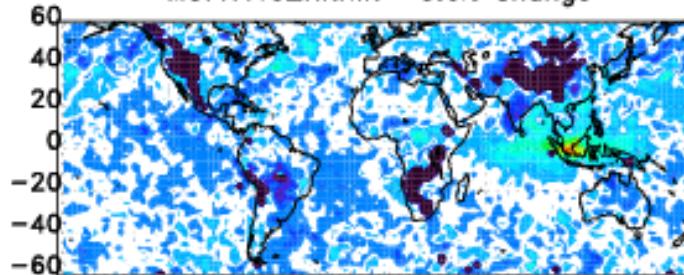
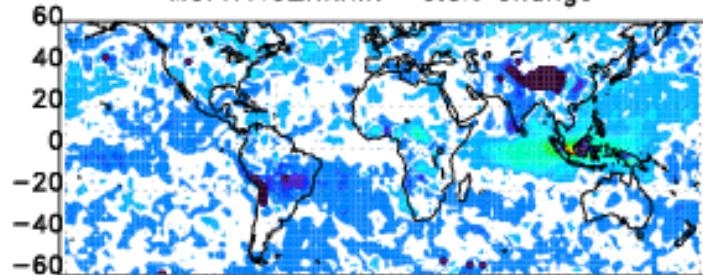
AIRSv6 1.1% Change



# LtropCO:Nino(06)–Nina(07) Oct15–Nov14

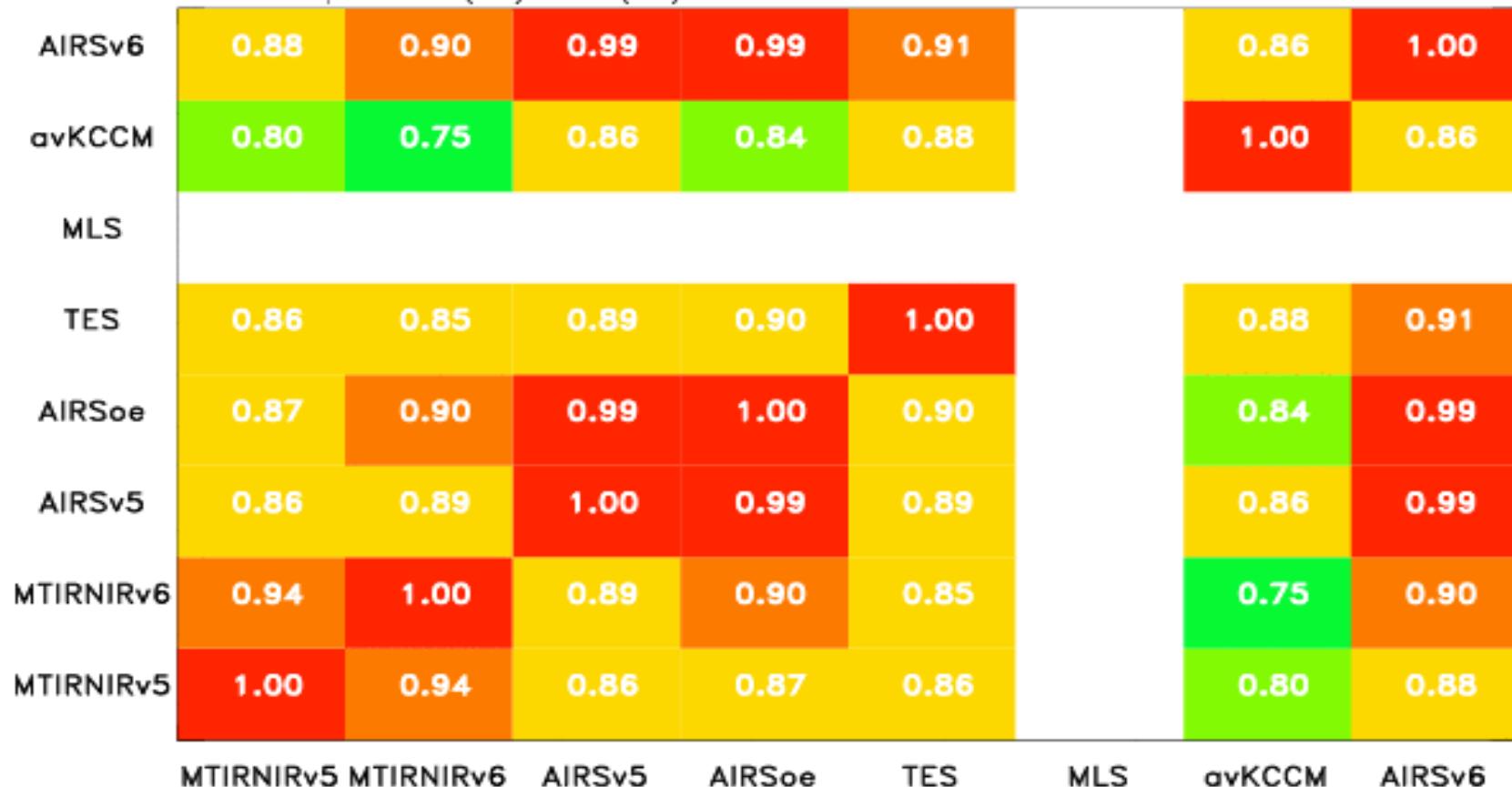
MOPITTv5\_TIRNIR 0.3% Change

MOPITTv6\_TIRNIR 0.6% Change



2x2.5MOPITT 850 hPa 2x2.5AIRSv5 850 hPa 2x2.5AIRSv6 850 hPa 4x5TESv5 908 hPa 2x2.5AIRSv6 850 hPa

MtropCO:Nino(06)–Nina(07) Oct15–Nov14 Correlation 180W–180E 60S–60N



\*\*\*\* \*\*\*\* 0.00 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00  
Correlation coefficient

UtropCO:Nino(06)–Nina(07) Oct15–Nov14 Correlation 180W–180E 60S–60N

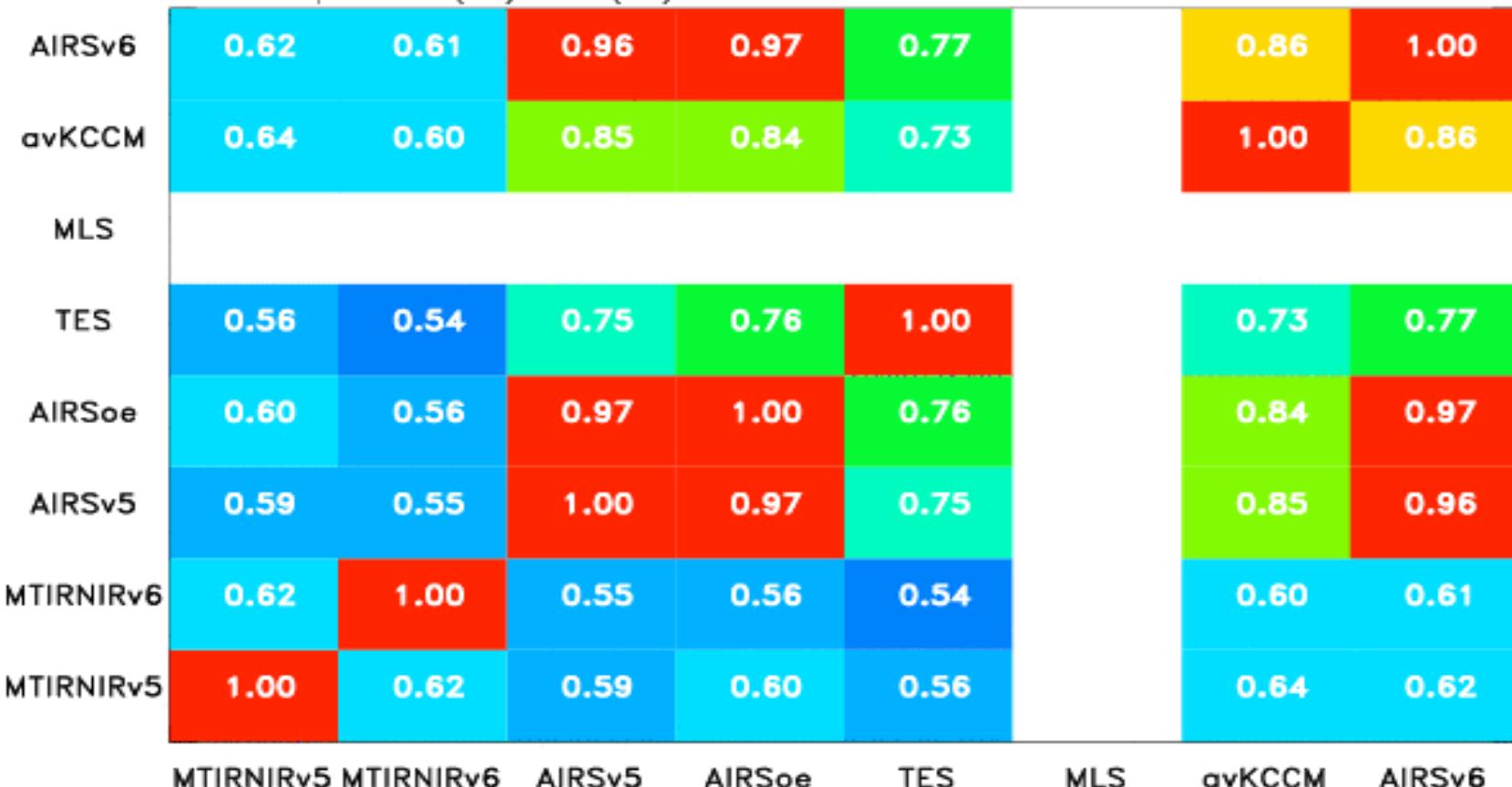


MTIRNIRv5 MTIRNIRv6 AIRSv5 AIRSoe TES MLS avKCCM AIRSv6



\*\*\*\* \*\*\*\* 0.00 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00  
Correlation coefficient

LtropCO:Nino(06)–Nino(07) Oct15–Nov14 Correlation 180W–180E 60S–60N



\*\*\*\* \*\*\*\* 0.00 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00  
Correlation coefficient

LtropCO:Nino(06)–Nino(07) Oct15–Nov14 Correlation 180W–180E 60S–60N



\*\*\*\* \*\*\*\* 0.00 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00  
Correlation coefficient

# Summary of CO comparison

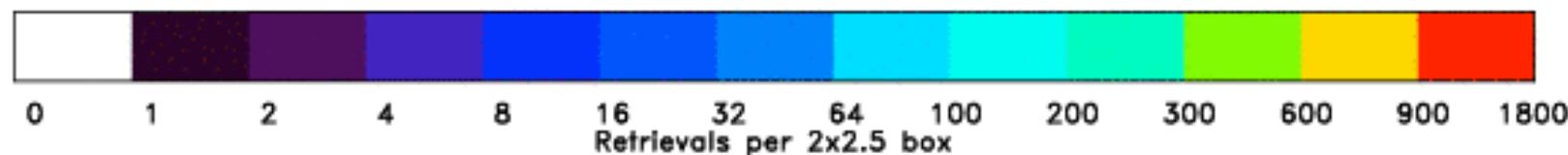
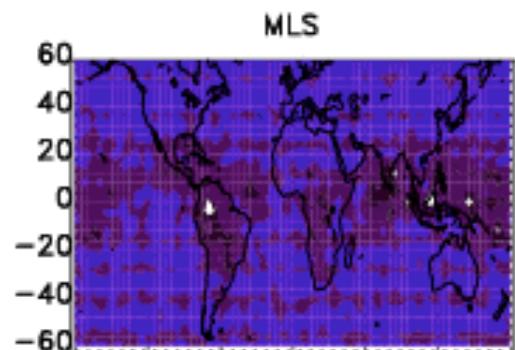
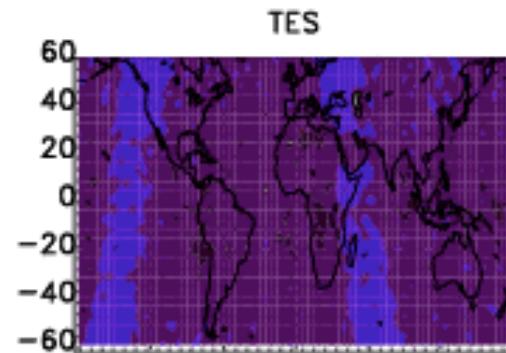
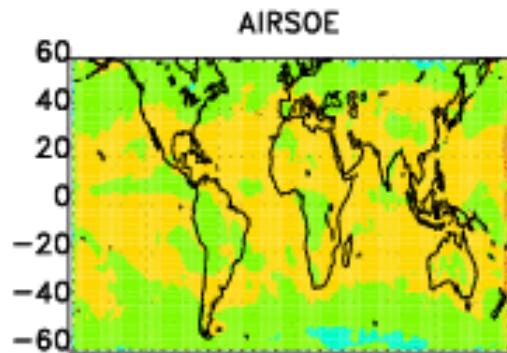
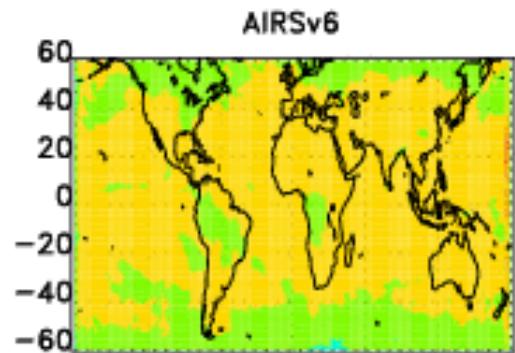
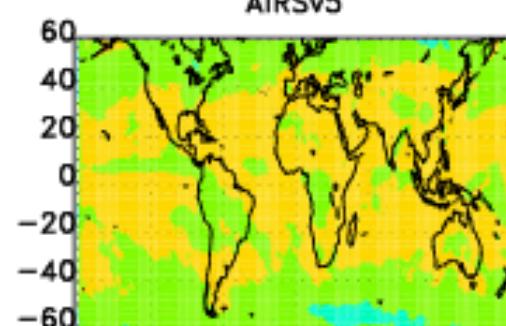
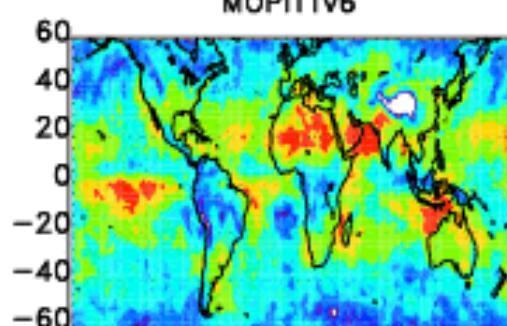
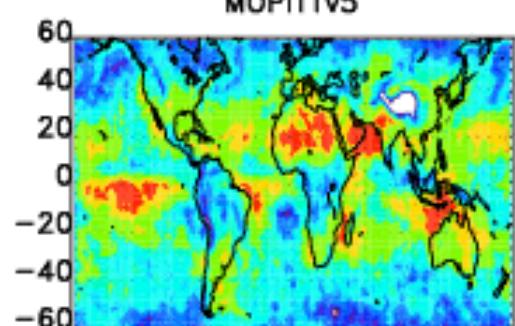
- **Midtroposphere**
- Strong Indonesian (Brazilian) fire signal in 2006 (2007)
- AIRS products have high bias wrt MOPITT
- MOPITT product shows pronounced minimum in northern subtropics
- Products are similar south of 20°S
- TES has low-bias in extratropics wrt MOPITT/TES
- **Upper troposphere**
- All products show peak in tropics with peak values varying by ~50%
- MOPITT v5 product (esp TIRNIR) has high-bias (v6 much better)
- AIRS products have tropical low-bias wrt MOPITT.
- **Lower troposphere**
- AIRSv5 and AIRSoe products biased high in SH (a priori)
- Fire signal is most prominent in AIRSoe product
- Anthropogenic signal seen in MOPITT and to a lesser degree TES products
- CO amounts change substantially between AIRS & MOPITT versions

## Summary of 2006-2007 correlations plots

- AIRS-based estimate of 2006-2007 change does not depend on AIRS version ( $R > 0.95$  between AIRS products at all altitudes)
- MOPITT-based estimate of 2006-2007 change does depend on version of TIRNIR product. ( $R=0.62$  between V5 & V6 in lower troposphere). V6 product likely better.
- Inter-satellite correlations of 2006-2007 changes are 0.85-0.95 in MT, 0.70-0.85 in UT, and 0.50-0.75 in LT
- Correlations between UT MLS CO and UT AIRS/MOPITT CO (0.66-0.76) are lower than correlations between UT TES CO and UT AIRS/MOPITT CO (0.72-0.88).
- In lower troposphere, correlation between TIRNIR-retrieved changes and changes from other products are relatively low (this is a good thing).

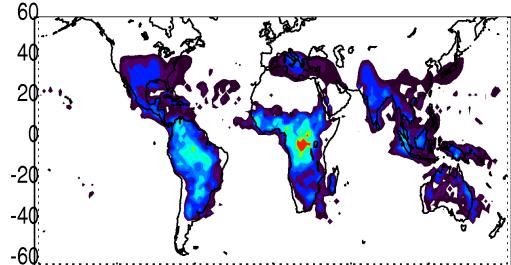
# Extra Slides

# Number of valid Utrop rets 20061015–20061114

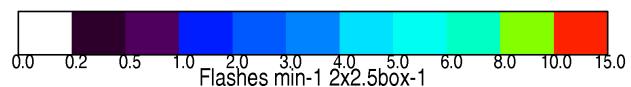
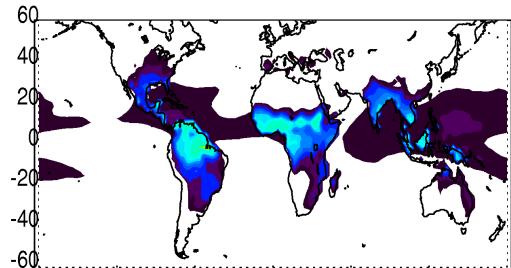


## Mean flash rate 20070901-20071130

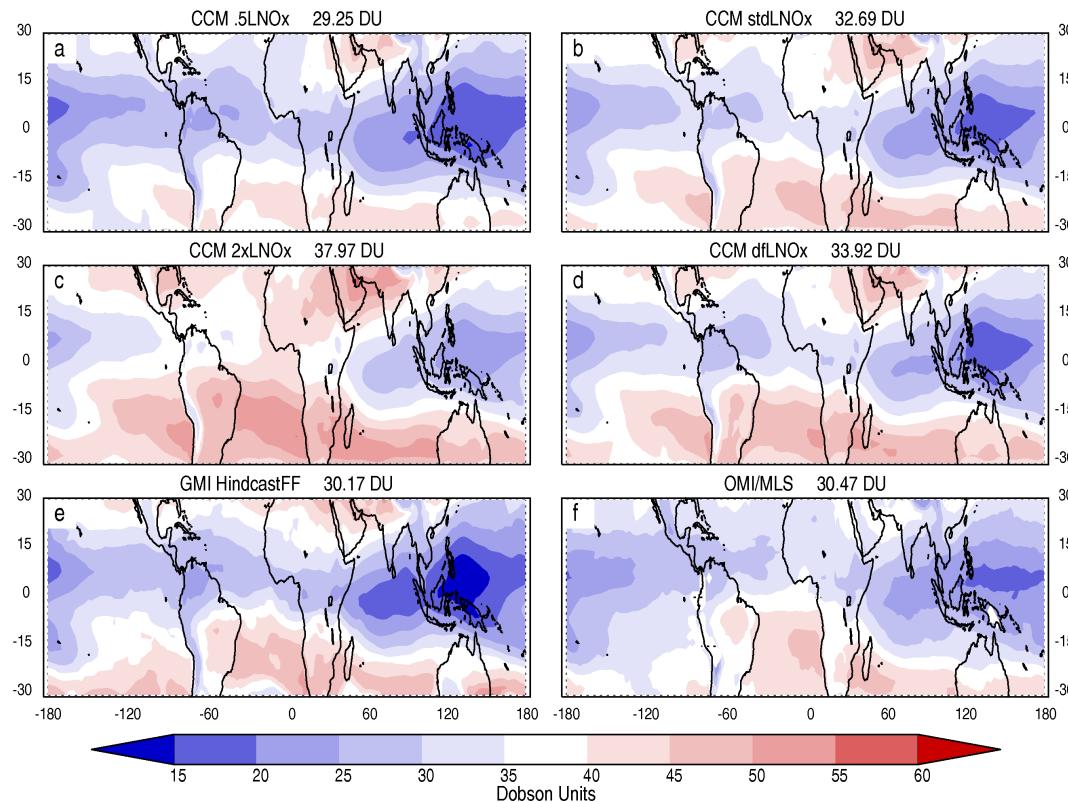
v2.3 OTDLIs 49.3 F s<sup>-1</sup>



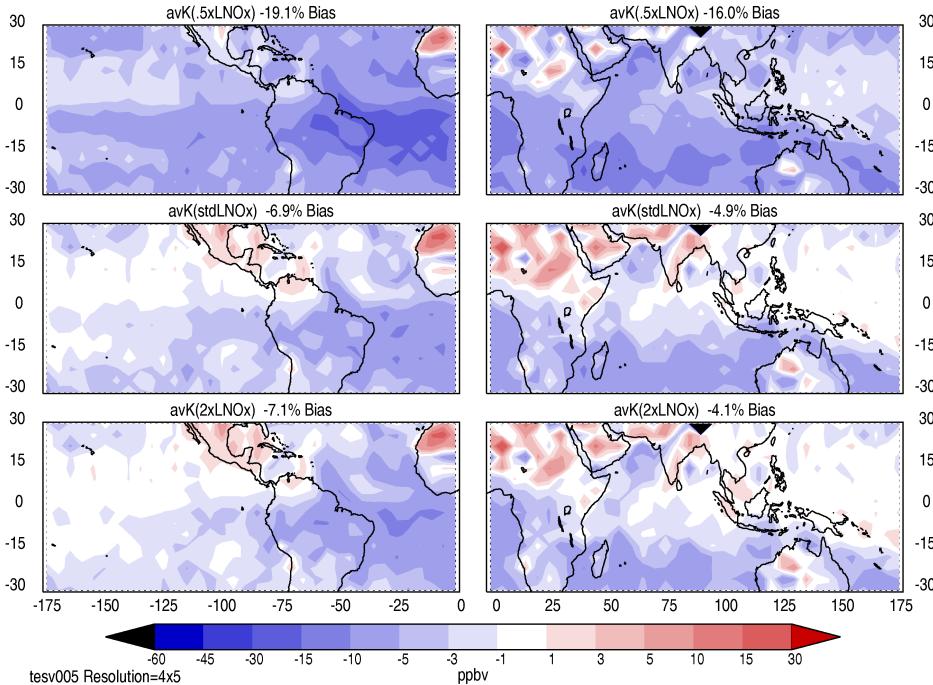
CCM 47.6 F s<sup>-1</sup>



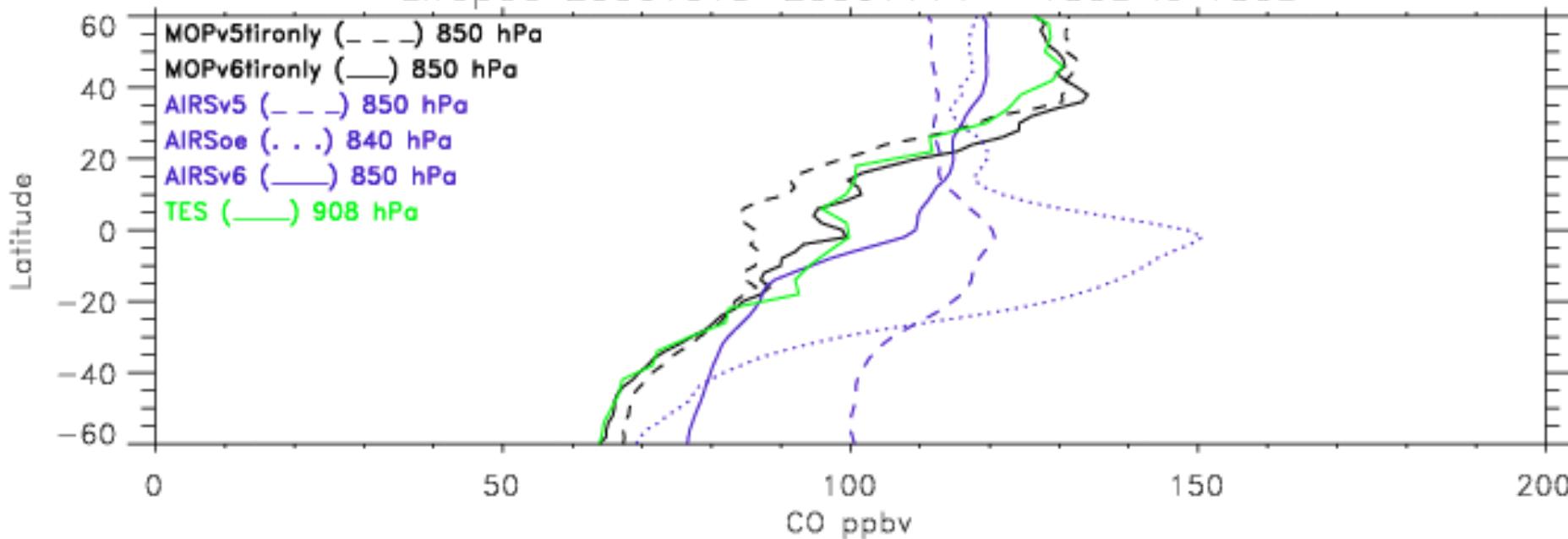
## NASA-GSFC CCM, GMI Hindcast and OMI/MLS TCO



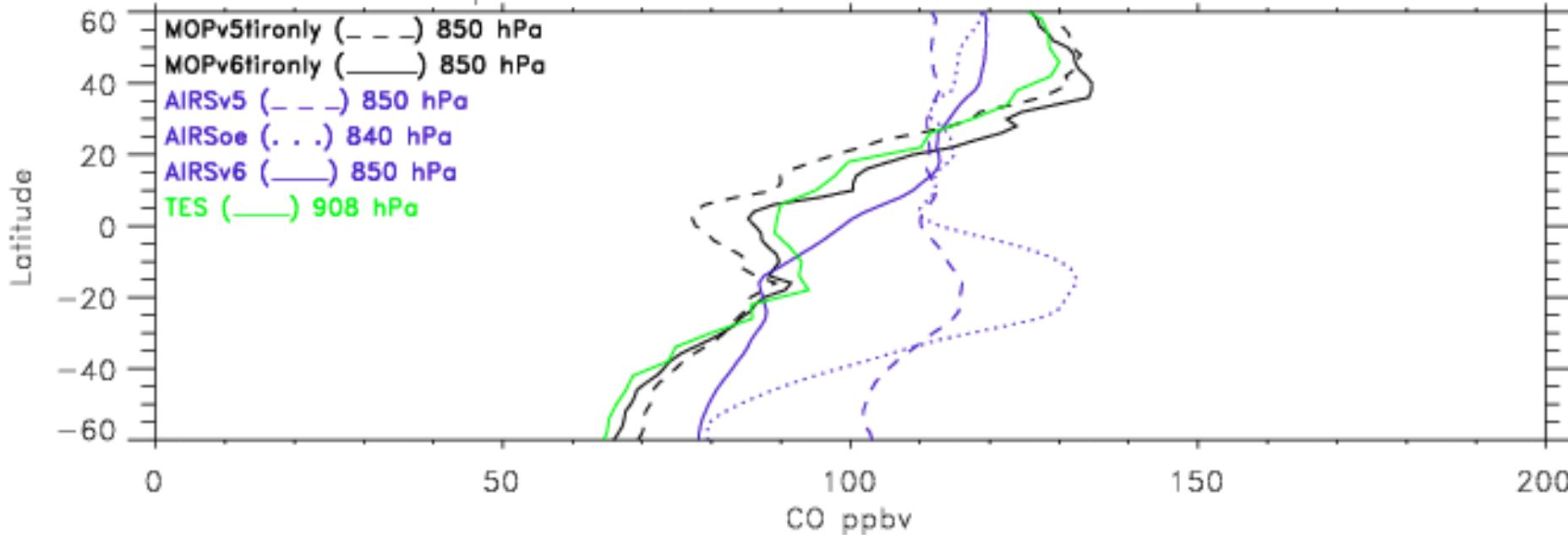
(ii) Mean O<sub>3</sub> Bias with Respect to TES at 825 hPa



LtropCO 20061015–20061114 -180E to 180E

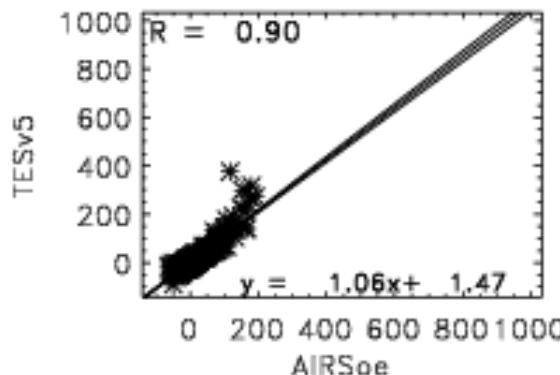
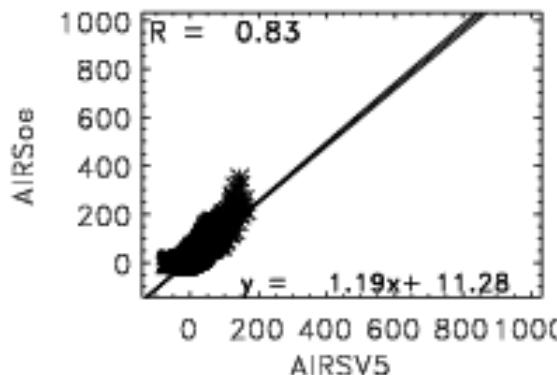
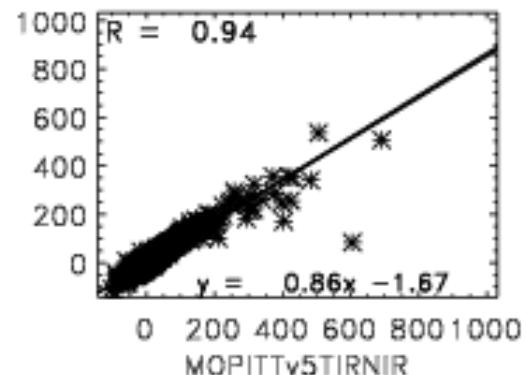


LtropCO 20071015–20071114 -180E to 180E

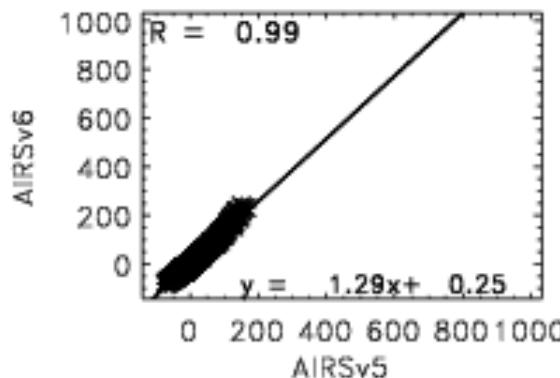
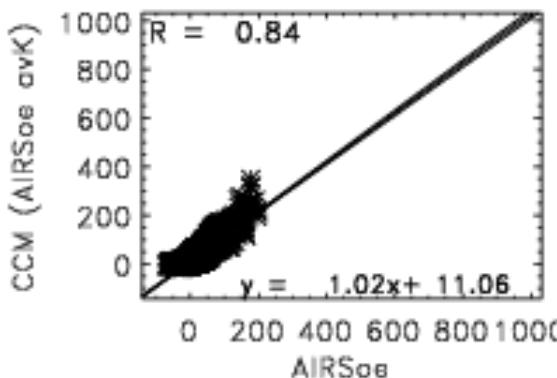
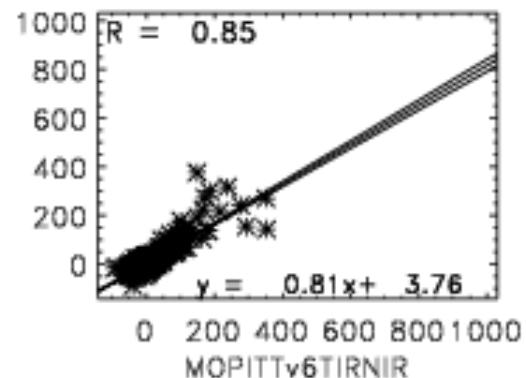


# MtropCO:Nino(06)–Nina(07) Oct15–Nov14

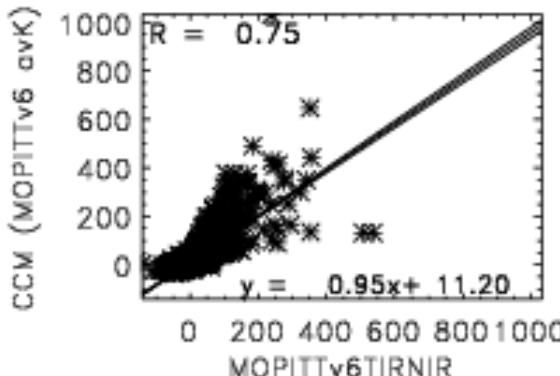
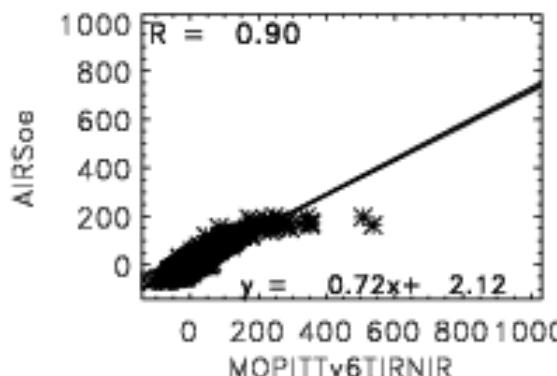
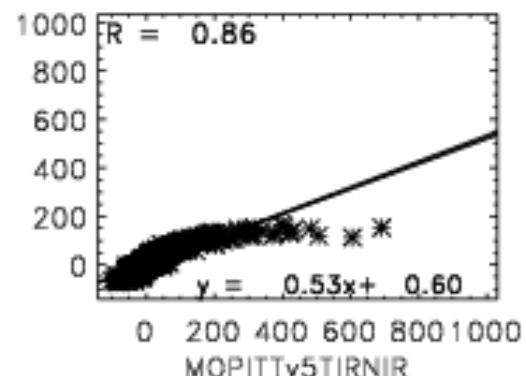
MOPITTv6TIRNIR



TESv5



AIRSv5



2x2.5MOPITT 500 hPa

2x2.5AIRSv5 500 hPa

2x2.5AIRSv6 500 hPa

180W–180E 60S–60N

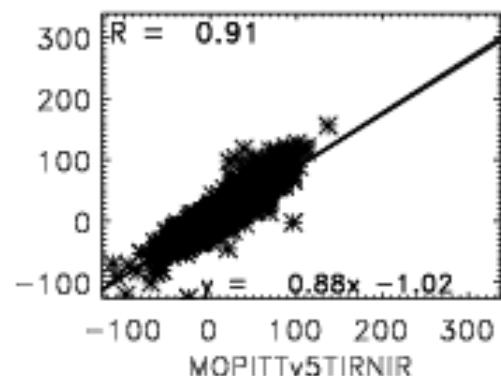
2x2.5AIRSv6 506 hPa

4x5TESv5 510 hPa

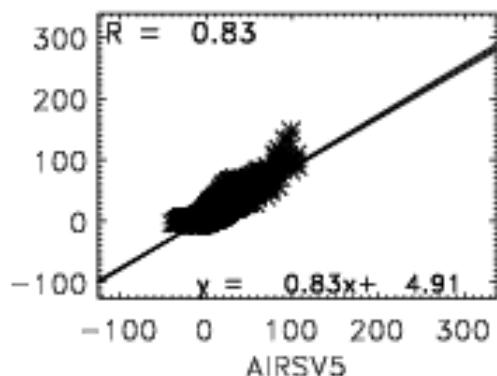
2x2.5AIRSv6 500 hPa

# UtrOpCO:Nino(06)–Nina(07) Oct15–Nov14

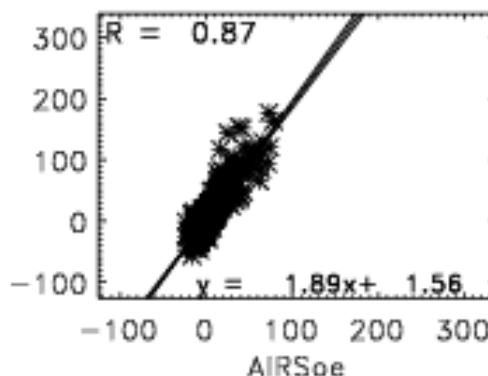
MOPITTv6TIRNIR



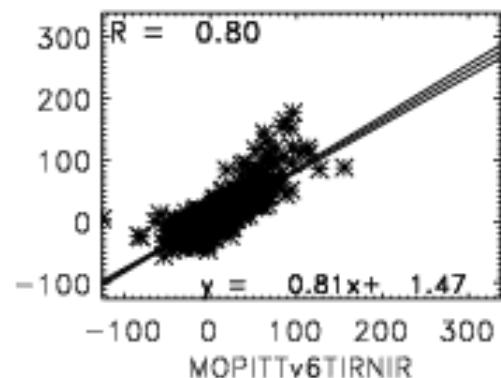
AIRSoe



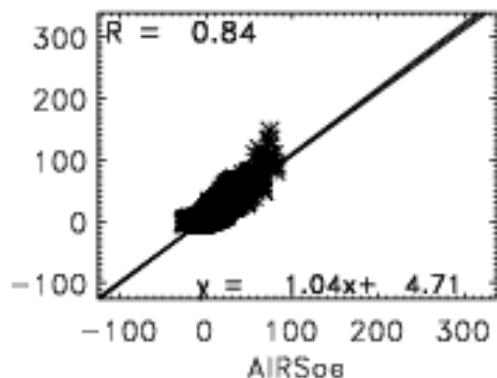
TESv5



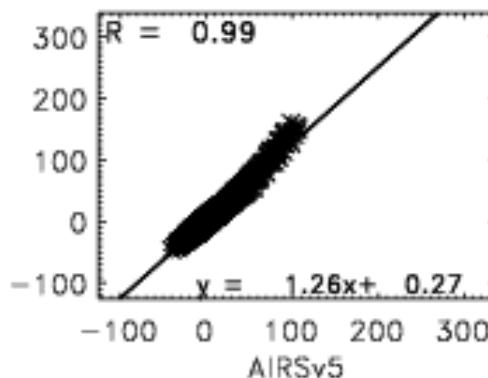
TESv5



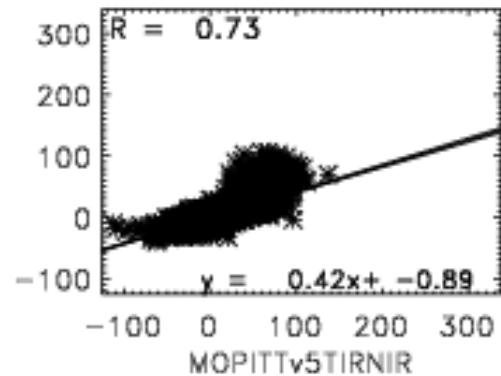
CCM (AIRSoe avK)



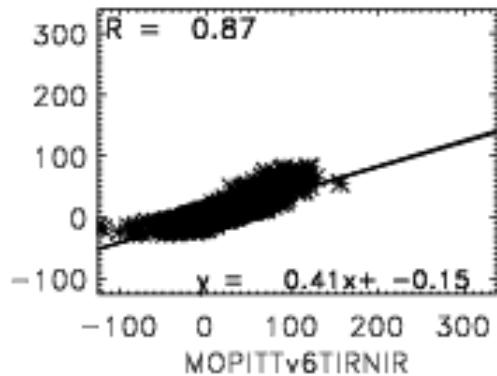
AIRSV6



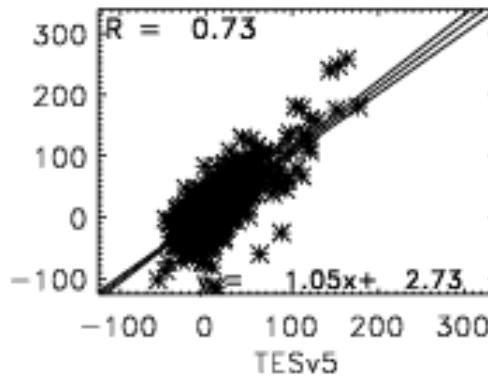
AIRSV5



AIRSoe

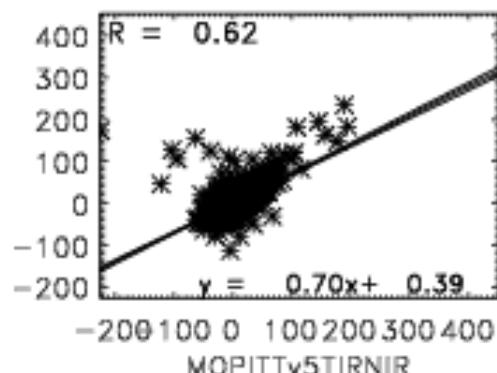


MLS

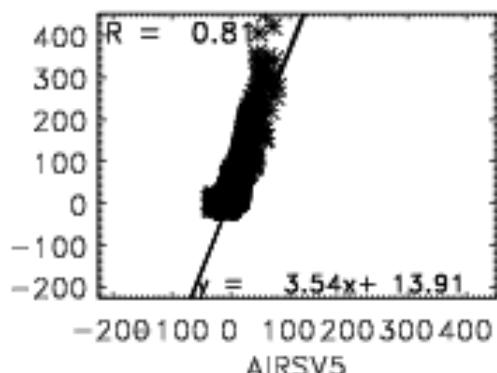


# LtropCO:Nino(06)–Nina(07) Oct15–Nov14

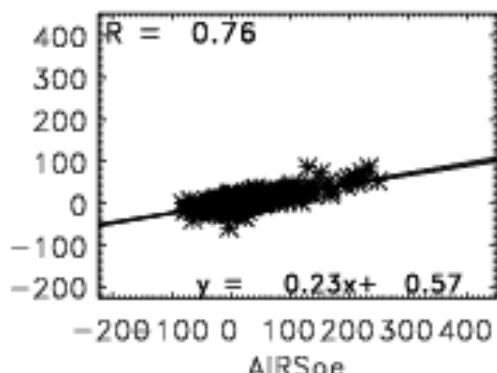
MOPITTv6TIRNIR



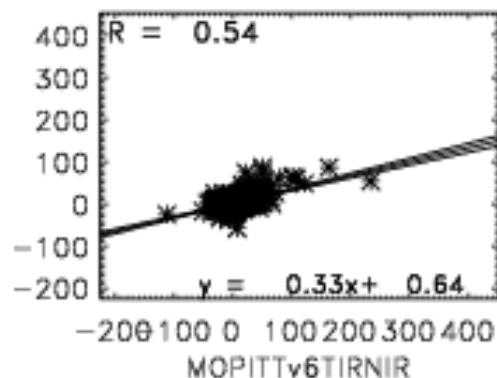
AIRSoe



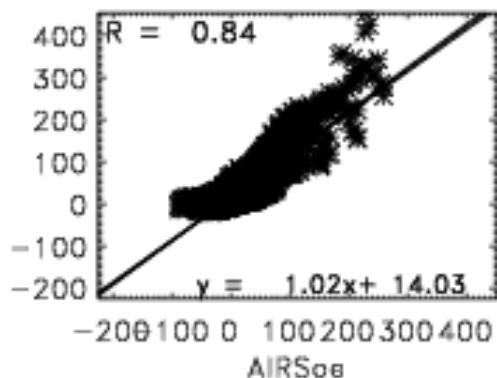
TESv5



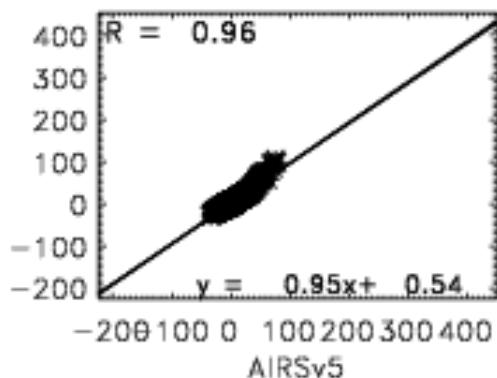
TESv5



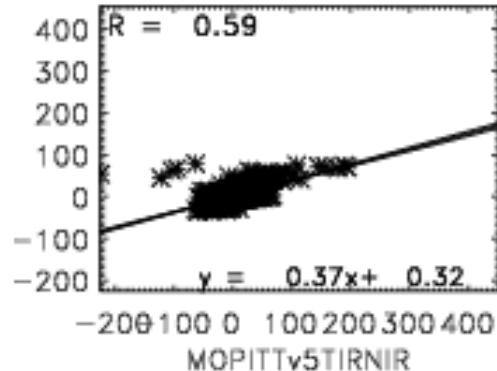
CCM (AIRSoe avK)



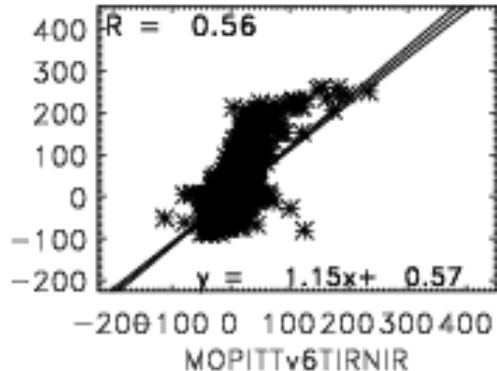
AIRSV6



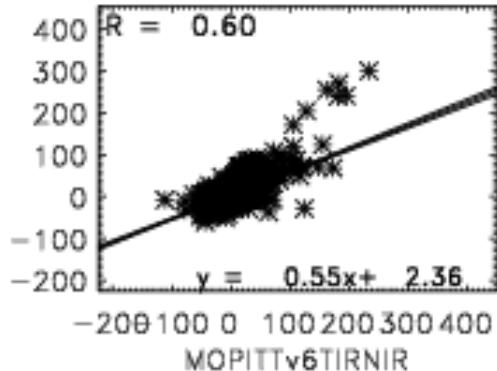
AIRSV5



AIRSoe



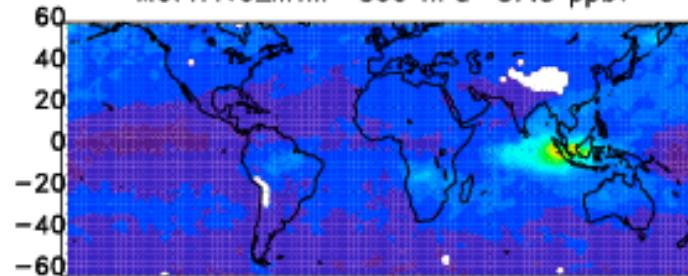
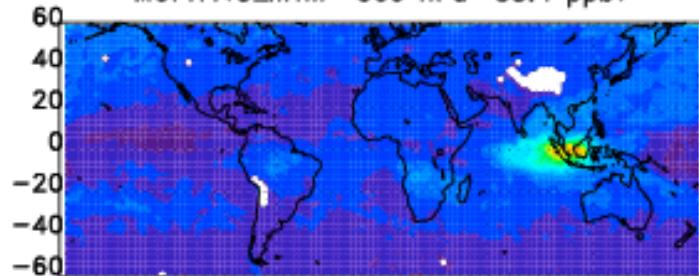
CCM (MOPITTv6 avK)



# MtropCO 20061015–20061114

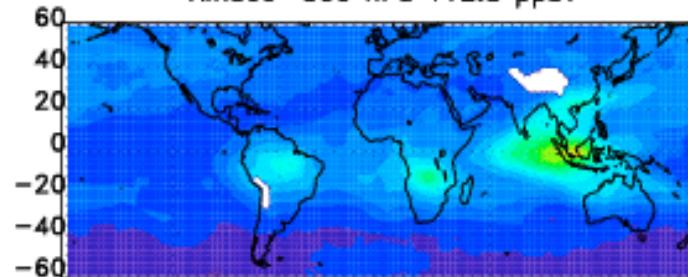
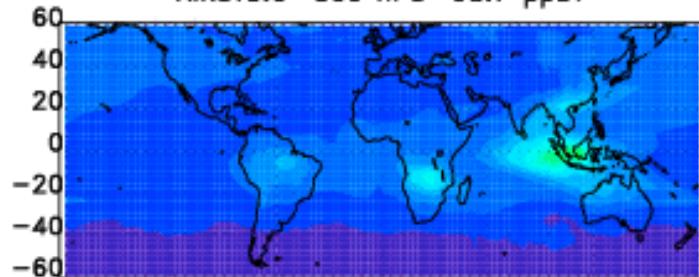
MOPITTv5\_tirnir 500 hPa 88.4 ppbv

MOPITTv6\_tirnir 500 hPa 87.8 ppbv



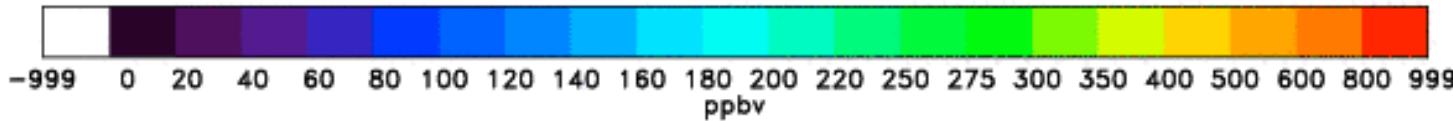
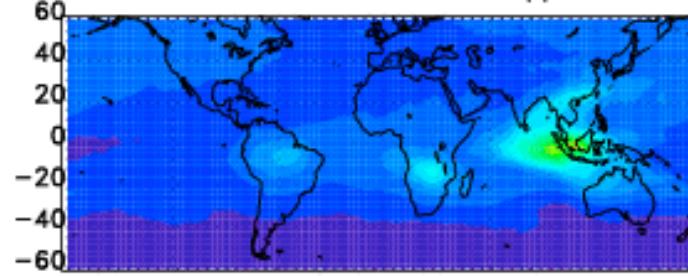
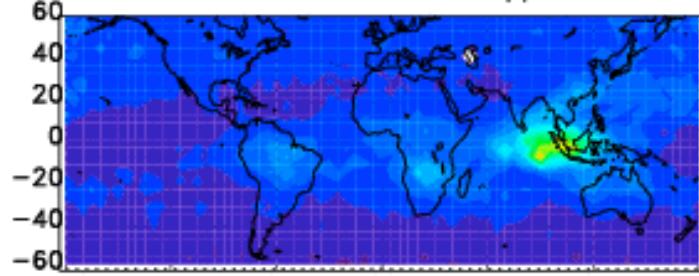
AIRSV5.0 500 hPa 98.7 ppbv

AIRSoe 506 hPa 112.8 ppbv



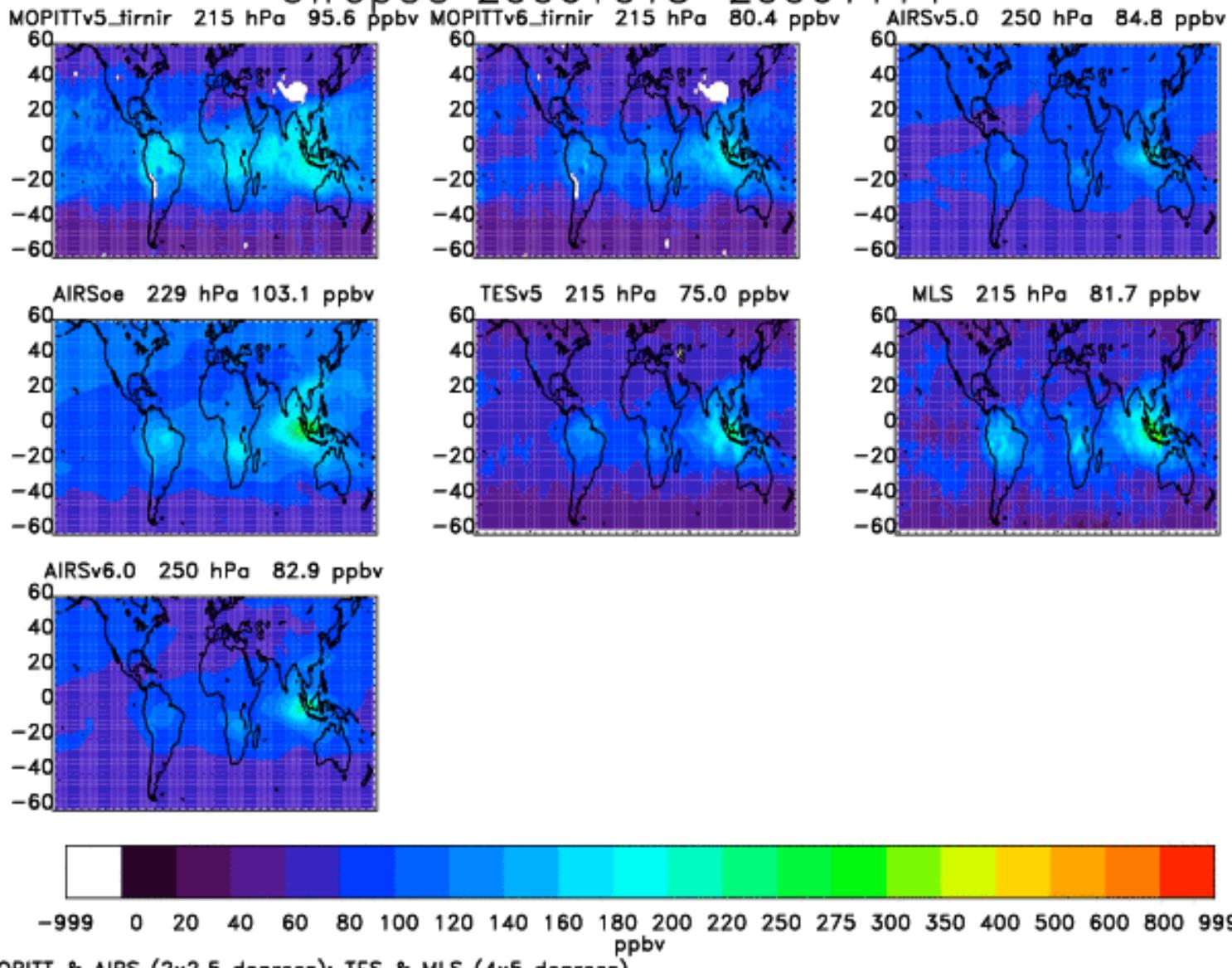
TESv5 510 hPa 90.5 ppbv

AIRSV6.0 500 hPa 99.6 ppbv

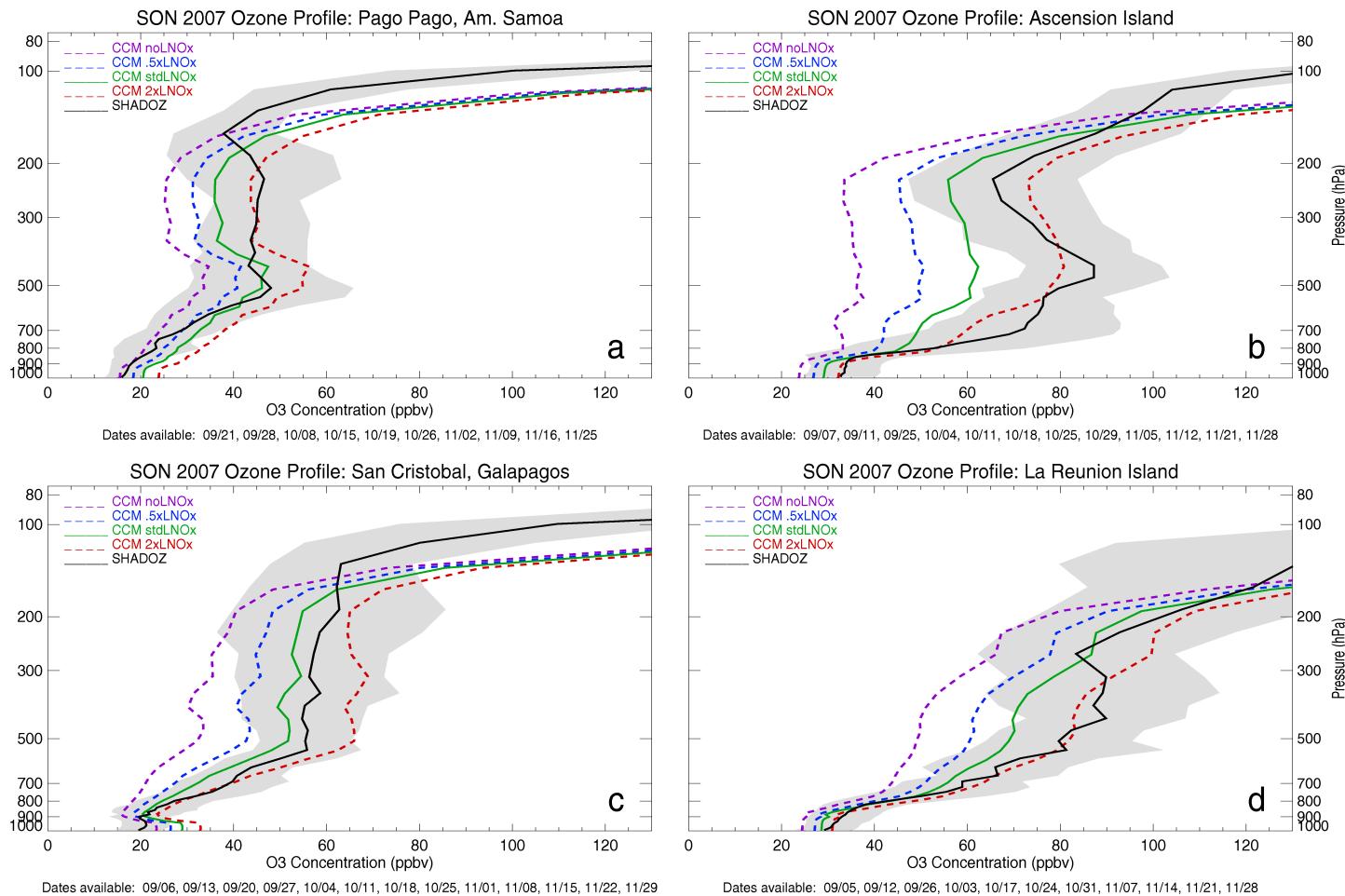


MOPITT & AIRS (2x2.5 degrees); TES & MLS (4x5 degrees)

# UtropCO 20061015–20061114



MOPITT & AIRS (2x2.5 degrees); TES & MLS (4x5 degrees)



**SHADOZ ozone (Thompson et al., 2012)**